Enhancing Transportation Project Delivery Through Watershed Characterization

SR-167 Study

Report to the WSDOT Urban Corridors Office

Authors

Richard Gersib

Tim Hilliard	Kevin Lautz
Tanya Johnson	Ed Molash
Joanne Neugebauer-Rex	Jim Park
Albert Perez	Kathy Prosser
Rob Schanz	Liora Van Natta

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Note: Other supporting materials (GIS data and metadata, background information, analysis) are available upon request. For more information, contact Richard Gersib, gersibd@wsdot.wa.gov or 360-705-7477.

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Watershed Characterization Technical Team

The Watershed Characterization Technical Team during the watershed characterization for the SR-167 project consisted of the following people:

Richard Gersib (WSDOT) ecologist, technical team leader

Tim Hilliard (WSDOT) policy specialist

Ed Molash (WSDOT) stormwater engineer

Joanne Neugebauer-Rex (contract employee) wetland biologist

Jim Park (WSDOT) hydrologist, floodplain specialist

Rob Schanz (contract employee) hydrologist, hydrogeologist

Liora Van Natta (contract employee) riparian analyst

Kevin Lautz (WSDOT) hydrologist

Geographic Information System technical support was provided by:

- Albert Perez (WSDOT) GIS analyst
- Kathy Prosser (WSDOT) GIS analyst
- Tanya Johnson (WSDOT) GIS analyst

List of Acronyms and Abbreviations

B-IBI	Benthic – Index of Biological Integrity
BMP	Best Management Practice
CARA	Critical Aquifer Recharge Areas
cfs	cubic feet per second
DAU	Drainage Analysis Unit
Ecology	Washington State Department of Ecology
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
I-	Interstate
SR-	State Route
TIA	Total Impervious Area
WRIA	Water Resources Inventory Area
WSDOT	Washington State Department of Transportation

Executive Summary

What is in this document?

This document presents the work of an interdisciplinary technical team of scientists charged with developing, implementing, and refining watershed characterization methods that support transportation project delivery. Here, we focus our efforts on a series of proposed transportation projects located along State Route 167 (SR-167) in King and Pierce Counties, Washington. The projects extend from the intersection with Interstate 405 (I-405) in the City of Renton, south on SR-167 to the Puyallup (SR-512) interchange. It crosses portions of the Green / Duwamish watershed and the watershed of the Puyallup River. The Green / Duwamish watershed is Water Resource Inventory Area (WRIA) 9 and the Puyallup / White watershed is WRIA 10.

> Watershed characterization is a technical tool used to answer the question *"Where should we target natural resource improvements to mitigate impacts of a transportation project while achieving the greatest environmental benefit at reduced cost?"*

This report provides the SR-167 project management teams with technical information for environmental documentation and options to consider when fulfilling regulatory requirements to treat stormwater flow control and avoid, minimize, and compensate for unavoidable natural resource impacts of the transportation project. While this list serves as an initial screen for prioritizing each site's potential to provide environmental benefits at both the site and landscape scales, additional work will be needed (such as identifying a willing seller and quantifying restoration feasibility and resource and functional gains) prior to final site selection. This report can also serve as a valuable mitigation resource to other management teams having transportation projects in the 350 square mile study area. Finally, this report serves to document the continued development and refinement of watershed characterization methods.

Watershed characterization is a technical tool used to answer the question "Where should we target natural resource improvements to mitigate impacts of a transportation project while achieving the greatest environmental benefit at reduced cost?" In the past, on-site mitigation was often the primary mitigation option. When site attributes limited potential to apply standard Best Management Practices (BMPs), mitigation cost skyrocketed and environmental benefits were marginal. Under these conditions, watershed characterization can offer a suite of new off-site mitigation options that are capable of meeting mitigation needs, while increasing environmental benefits and reducing mitigation cost.

Our goal is to provide the project management team with information and alternative mitigation options that have the potential to increase environmental benefits while reducing mitigation costs. To achieve this goal, we first gain understanding of the location and condition of natural resources at both the project site scale and a larger landscape scale. At the project site scale, we gain an understanding of the potential project impacts to existing natural resources. We also rank existing wetland sites within the project area to assist the project management team in their decision-making process to avoid and minimize impacts to wetland resources.

At the landscape scale, we characterize the condition of key ecological processes (aquatic integrity, forest patch density, movement of water, sediment, and large wood) that the transportation project impacts. We do this by interpreting existing land cover and natural resource data and by developing databases that identify the location and condition of wetland, riparian, and floodplain resources. We then identify targeted landscape areas having the potential to optimize environmental benefits if restored.

At the site scale, we identify all possible candidate wetland, riparian, and floodplain restoration sites through photo interpretation of the study area. In addition to creating these natural resource datasets, we developed a stormwater retrofit database to provide additional options for treating stormwater in urban areas where few viable natural resource options exist. The technical team established priority criteria and then ranked all candidate mitigation sites for stormwater flow control (Appendix A), overall ecosystem function (Appendix B), and fish habitat (Appendix C). The stormwater flow control priority list is intended specifically for identifying potential wetland and floodplain restoration sites as well as stormwater retrofit options that have potential to mitigate stormwater flow control impacts of the transportation project. The natural resource mitigation priority list is intended to identifying sites that maximize overall ecosystem function, and provides the project management team with options for the mitigation of wetland, floodplain, and habitat mitigation needs of a project. Finally, the fish habitat priority list ranks potential wetland, floodplain, and riparian restoration sites to maximize habitat benefits to anadromous fish species.

What are the general findings of this study?

At a landscape scale, we found that the condition of natural systems generally transitioned from “not properly functioning” within the Kent / Auburn valley on the western or commercial / urban portions of the study area to a more “at risk” condition in the eastern parts of the study area. At the project scale, the SR-167 project will have substantial stormwater impacts and likely wetland and habitat impacts what will require compensation or mitigation. We evaluated two project development scenarios. Scenario 1 added one lane in both northbound and southbound directions throughout the entire SR-167 corridor, while Scenario 2 added two lanes in both directions.

Prior to avoidance and minimization efforts, we estimate that Scenario 1 would result in nearly 60 acres of wetland impacts, and less than 10 acres of potential riparian and floodplain impacts. While we assume that water quality treatment can be done within the project area, we estimate that stormwater flow control needs could approach 250 acre-feet of storage within the corridor. In addition to these potential natural resource impacts, we estimate that 1,738 linear feet of salmonid fish-bearing streams occur within the impact area of Scenario 1.

Prior to avoidance and minimization efforts, we estimate that Scenario 2 would result in nearly 150 acres of wetland impacts, nine acres of impacts to forested riparian areas, and 19 acres of potential floodplain degradation. We estimate that stormwater flow control requirements could approach 290 acre-feet of storage throughout the corridor, and fish habitat on 1,940 linear feet of salmonid fish-bearing streams could be affected.

To identify and evaluate potential mitigation opportunities, we used watershed characterization to identify degraded wetland, floodplain, and riparian resources. We then used our understanding of landscape condition to place each potential mitigation site in a landscape context. We evaluated and prioritized mitigation sites in this context. In the study area, we evaluated nearly 4,000 riparian areas, over 1,700 wetland areas, 67 floodplain areas, and 10 stormwater retrofit sites for mitigation potential and environmental benefit.

Of these sites, 1,026 potential wetland, floodplain and riparian restoration sites met our minimum criteria for potential use for mitigation. We prioritized those sites for optimizing overall ecosystem function. In addition, 569 sites (559 potential wetland, floodplain, and riparian restoration sites and 10 stormwater retrofit sites) met minimum criteria for potential use for stormwater flow control. We prioritized those sites for stormwater flow control. Finally, 1,026 potential wetland, floodplain, and riparian restoration sites met minimum criteria for anadromous fish habitat and were prioritized for habitat.

Although we identify flow control storage volumes and mitigation for all of the project drainages, several of these areas may not require stormwater flow control. The areas that drain to the mainstem White River will likely be exempt from flow control standards. The mainstem Green River is not currently on the list of exempt waterbodies, but could possibly be added in the future.

I. Introduction to Watershed Characterization

What is watershed characterization?

Watershed characterization is a process initiated, prior to transportation project planning and design, that provides the project office with:

- A general understanding of the location and extent of natural resources on or adjacent to the project area.
- An estimate of potential project impacts to regulated natural resources.
- Information and tools to facilitate natural resource avoidance and minimization, information on landscape condition of the project and study areas.
- A prioritized list of candidate wetland, riparian, and floodplain restoration sites that have potential to maximize environmental benefits.

Watershed characterization is a series of steps that identify, screen, and prioritize hundreds of potential wetland, riparian, and floodplain restoration sites. These steps focus on gathering pertinent watershed data needed to establish an understanding of where landscapes are and are not functioning properly, where degraded natural resources exist, and where to target mitigation to maximize environmental benefits. In the end, this analysis will allow WSDOT to choose mitigation sites that will provide the greatest functional replacement, have a high probability of being successful, expedite permit processing, and ensure that we get the highest value for our investments.

Through watershed characterization, the interdisciplinary technical team seeks to integrate the mitigation of wetland, riparian, floodplain, and stormwater impacts by restoring the landscape's capacity to function. We do this by assessing the condition of ecological processes, such as the movement of water, sediment, pollutants, large wood, and heat and aquatic integrity and forest patch density. We then target restoration to degraded natural wetlands, riparian areas, and floodplains having the greatest potential to mitigate project impacts and result in measurable environmental benefits. We also place special emphasis on the development of tools capable of identifying natural resource restoration sites having potential to help meet project stormwater flow control needs.

WSDOT's watershed characterization is a planning tool that identifies alternative mitigation opportunities to conventional stormwater flow control BMPs and on-site wetland and habitat mitigation options. It is the initial screening tool to identifying candidate mitigation sites. This work will then require more focused site assessment to determine site availability, viability, and cost effectiveness.

Why does WSDOT conduct watershed characterization?

A transportation project within the watershed characterization study area can benefit from this work by using products to:

- Support and facilitate environmental documentation and permitting.
- Better understand potential environmental impacts and mitigation needs.
- Facilitate improved natural resource avoidance and minimization decision-making.
- Better understand areas of greatest environmental risk to project delivery.
- Identify and screen hundreds of new mitigation options, available nowhere else.
- Focus the search for mitigation opportunities on sites that have the greatest potential to compensate for unavoidable natural resource impacts and maximize overall environmental benefits to the watershed and local recovery efforts.
- Reduce the cost of mitigating unavoidable natural resource impacts.
- Target the search for large candidate mitigation sites for more detailed evaluation and potential use as conservation banks.
- Identify alternative offsite stormwater flow control options when conventional stormwater flow control best management practices are not feasible or cost effective.

A landscape perspective can help us make better mitigation decisions by allowing us to place individual mitigation sites in a landscape context. This allows us to build on the site condition information already being compiled to provide a more complete picture of the potential each mitigation site has to mitigate environmental impacts and maximize environmental investments.

How do we conduct a watershed characterization?

Watershed characterization consists of three key analysis steps.

- In Step I, we analyze the condition of landscape-scale ecological processes and the extent of human alteration to these systems. Key physical processes include the movement of water, sediment, pollutants, large wood, and heat through stream systems within the study area. Key biological processes include aquatic integrity and forest condition.
- In Step II, we identify and estimate the potential direct project impacts to natural resources within the project area.

- In Step III, we identify and rank potential mitigation sites.

At a landscape scale, we subdivided the SR-167 study area into 238 smaller stream catchments and used landscape attributes to characterize how land use change has altered the natural movement of water, sediment, pollutants, and large wood, along with aquatic integrity. Then, using statistical tools, we evaluated upland forest density at a larger scale. We use this information to target restoration efforts within landscapes that have the greatest potential to restore and maintain environmental benefits over the long-term.

At a site scale, we identified natural resources on or adjacent to the SR-167 corridor and then created probable project impact areas based on development scenarios provided by the project office. With WSDOT's MGS flood model, we estimate flow impacts and storage needs from retrofitted and new impervious areas. We use fish distribution data and probable project impact areas created for each development scenario to estimate the potential extent and types of fish habitat impacts that can be expected prior to avoidance and minimization efforts. We use this information to estimate the location, type, and magnitude of potential project impacts to regulated natural resources.

We created potential restoration site datasets for wetlands, riparian areas, and floodplains which we use to identify potential mitigation sites. We also identify where stormwater retrofit projects could address existing stormwater runoff problems. We use available data and extensive photo interpretation to develop wetland, riparian, and floodplain datasets. These datasets differ significantly from existing natural resource data, such as local governments might develop, in that we seek to identify potential restoration sites rather than inventorying existing wetlands, riparian areas, and floodplains. These potential restoration sites include intact existing wetlands and degraded or destroyed wetlands that have potential, if restored, to meet mitigation needs.

The technical team establishes both site and landscape criteria to evaluate and rank potential floodplain, wetland, and riparian restoration and stormwater retrofit sites. This process results in two prioritized mitigation site lists; one for potential natural resource mitigation sites (with potential floodplain, wetland, and riparian restoration sites) and one for potential stormwater flow control sites (with floodplain restoration, wetland restoration, and stormwater retrofit sites.

More details on methods used in watershed characterization can be found in the Appendix of this report and our current methods document found at this web address:

http://www.wsdot.wa.gov/environment/watershed/technical_report.htm

How was local information and expertise acquired and used?

An important part of the watershed characterization efforts is coordination with local and regional governmental entities and watershed groups. Our reasons for doing this are:

- To ensure that local natural resources managers and interest groups are aware of what we are doing within their area, what watershed characterization is, and how it works.
- To gain insight into local permitting criteria and policies.
- To ensure that information developed through watershed characterization is compatible with existing planning efforts by local, tribal, or regional governments, whenever possible.
- To acquire locally developed datasets of relevance to watershed characterization.
- To identify and acquire local watershed recovery plans, priorities, and locally identified restoration opportunities.

During the watershed characterization for the SR-167 project, we met in person or talked by phone with a variety of groups with natural resource interests in the study area. These interactions were intended to get background information, discuss data needs, communicate our purposes, and gain familiarity with the interested parties.

We also sent a series of “progress reports” to a wide mailing list of local, state, regional, and tribal governmental staff and other interested parties, detailing our progress and communicating data needs over this four month project.

An integral part of watershed characterization is the identification and use of locally identified themes. These themes are used, in part, to establish criteria for prioritizing potential mitigation sites.

We consulted draft and final reports containing watershed priorities for habitat restoration, salmonid recovery, water quantity and base flow improvements, and water quality improvements. Besides containing much valuable background, these were “mined” for lists of local restoration priorities. Later in the watershed characterization process, we matched these lists to our own mitigation site lists, affording higher priority to sites that were also local priorities.

Each of these documents contains locally defined projects or targeted stream reaches for water quality enhancement, runoff control, ecosystem recovery, salmon recovery, sediment control, flood amelioration, or similar benefits. We matched locally identified recovery sites to sites identified through watershed characterization and used this information to help prioritize our candidate mitigation sites found in Appendices A and B.

What are the project deliverables?

Watershed characterization deliverables for the SR-167 projects are:

- A prioritized list of potential stormwater flow control sites for the SR-167 corridor within the study area.
- A prioritized list of potential natural resource mitigation sites for overall ecosystem function in the SR-167 study area.
- Potential wetland, floodplain, riparian, and stormwater retrofit ArcMap data layers with all site-specific data.
- Extensive information on the landscape condition of key ecological processes.
- Extensive documentation of technical methods, assumptions, and results of watershed characterization in a manner that is comprehensive and understandable.

Our goal is to make this report clear and understandable to the average person, while still providing all of the technical documentation necessary to support science-based decision-making. To do this, we have chosen a multi-level presentation:

- In the main report body we use a format that seeks to "tell the story" of the study area and of our results
- We provide our detailed step-by-step results in the appendices
- We keep technical methods in a separate methods document
- Drilling even deeper, we will make our GIS data, modeling assumptions, and other technical details available on a CD as requested

We are hopeful that this format will be more understandable for the non-technical reader and yet ensure that all methods, data, assumptions, and results are readily accessible to technical and regulatory reviewers.

What are the limitations?

We have analyzed all the candidate floodplain, wetland, and riparian mitigation sites using aerial photo interpretation, but only a limited number have had preliminary field verification. The potential mitigation site priority lists developed through watershed characterization should be considered as the starting point for a more extensive site assessment effort by project environmental staff or their consultant support. This is, in reality, a recognition that the selection of the best potential mitigation sites requires both a landscape-scale assessment and a detailed site-specific analysis. Prior to a landscape-scale assessment, the process of identifying potential mitigation sites was often restricted to the identification of undeveloped land on or adjacent to the project area where wetlands could be created or enhanced through design and excavation. Regardless of the approach taken, detailed site-specific assessment will be required.

Watershed characterization products are limited by the number, location, and extent of potential wetland, floodplain, and riparian restoration sites within the study area. Contrary to engineered solutions, such as a detention pond or concrete underground vault, if no potential wetland restoration areas exist upslope of a stormwater discharge, watershed characterization has no viable options for the project engineer to consider. Watershed characterization is based on the restoration of degraded natural resources and is limited by the restoration options available.

In addition to these limitations, specific data limitations are noted throughout the technical reports located in the appendices.

II. The Study Area and the Transportation System

What is the study area and how was it defined and subdivided for analysis?

Our SR-167 study area is a 360 square mile area draining to and away from the proposed SR-167 projects (Figure 39, Study Area Base Map). This study area includes parts of the Green / Duwamish watershed and parts of the Puyallup watershed. Where practicable, we extended the study area to the edges of the Puget Lowlands ecoregion. In the lower reaches, we avoided including small streams that enter the main drainages below the highway projects.

The 360 square mile study area was subdivided into a series of nested spatial scales for analysis and the presentation of information. The study area was first divided into 18 stream subbasins (Figure 40, Subbasins Used in Analysis). To delineate these, we used a combination of subbasins that had been defined for use by various local watershed studies with our own Best Professional Judgment. These 18 subbasins were then subdivided into 225 DAUs, illustrated in Figure 41, Drainage Analysis Units.

What is the geography of the study area?

The study area for this watershed characterization consists of parts of two Water Resource Inventory Areas (WRIAs) – WRIA 9, the Green / Duwamish watershed, and WRIA 10, the Puyallup watershed. The watersheds and partial watersheds in the study area are a group of subbasins that drain into the Green River or the Puyallup River.

In the Green / Duwamish watershed, the study area contains the lower reaches of the Green River as far downstream as the confluence with the Black River at about River Mile 11 in Tukwila; and upstream to about River Mile 51 (in the Green River Gorge southeast of Black Diamond). It also includes many of the Green River tributaries including the Black River / Springbrook Creek system, Mill Creek, the Soos Creek system, and Newaukum Creek.

In the Puyallup watershed, the study area contains the lower reaches of the Puyallup from a point in Fife near I-5 (about River Mile 2.5) upstream to about a point south of Orting near the confluence of Fiske Creek (approximately River Mile 26.5). Important tributary streams to the Puyallup include the Lower White River to the Buckley area (about River Mile 26), the lower Carbon River to a point about three miles upstream of Orting (about River Mile 6) and South Prairie Creek to a point about four miles upstream of South Prairie (near River Mile 10). Smaller tributaries to the Puyallup in the study area include Fennel Creek, Canyon Falls Creek, Strawberry Creek, Bowman Creek, and parts of the Boise Creek, Wapato Creek, and Wilkeson Creek drainages.

The Lake Tapps system is important to address in the hydrologic analysis of the study area, although it is an artificial lake located out of the main stream channels. It was created by diverting water from the White River at about River Mile 24, near Buckley. The water is carried by flume and canal to the lake, and by tunnel and flume back to the White River at about River Mile 3.5.

Each of these drainages has similarities and differences in geology, topography, precipitation, hydrologic alteration, and human land use. We introduce these subjects in greater detail in subsequent sections of the document.

The study area includes a great number of local governmental jurisdictions. Approximately one quarter of the study area is in unincorporated areas of King and Pierce counties, but the rest includes all or part of 18 cities, as shown below:

- Algona
- Auburn
- Black Diamond
- Bonney Lake
- Buckley
- Covington
- Edgewood
- Enumclaw
- Fife
- Kent
- Maple Valley
- Orting
- Pacific
- Puyallup
- Renton
- South Prairie
- Sumner
- Tukwila

The Muckleshoot Indian Reservation is located in the study area and they also have treaty rights for fishing in all of WRIAs 9 and 10 (as well as other areas). The Puyallup Indian Tribe does not have a reservation in the study area but has treaty rights for fishing in all of WRIA 10 (as well as other areas). The tribes, along with state and federal agencies, are co-managers of the study area’s fisheries resources and the habitats that support them.

The entire study area lies in the Puget Lowlands ecoregion. Elevations range from less than 10 feet at the mouth of the Black River to about 3,100 feet at the summit of Boise Ridge. Much of the study area was worked and reworked by the Vashon Ice Sheet (as well as earlier ice sheets) resulting in a predominance of glacial deposits, including advance outwash, recessional outwash, and glacial till. Another large portion of the study area consists mostly of volcanic mudflow (lahar) deposits from the 5,600-year-old Osceola Mudflow and, from approximately 500 years ago, the much smaller Electron Mudflow (USGS/Cascades Volcano Observatory website). Bedrock outcrops consisting of volcanic and sedimentary rocks are rare in the study area but occur at the very northern end of the study area near the mouth of the Black River, and along the eastern edges of the study area from north of Black Diamond to south of Enumclaw, notably in the Green River Gorge. Along the lower reaches of larger streams there are extensive areas of post-glacial alluvium.

Land use in the study area ranges from highly urbanized areas to agriculture and forest. Some portions of the study area (especially downtown Kent, Auburn, Puyallup, and Sumner, as well as large parts of the Green River valley) are completely urbanized, and much of the western half of the study area is composed of moderate to high-density residential areas. The easternmost parts of the study area contain many moderate to high-density residential areas as well, while other parts are rural residential in character. Some areas east of Black Diamond and east of Enumclaw are managed as commercial forest. Some sizable areas west and south of Kent, as well as much more substantial areas on the Enumclaw Plateau, remain in agricultural land uses. Scattered areas near the streams and on plateaus in other parts of the study area are still in agriculture as well.

We provide more detail on the geography in individual subbasins in Chapter III, “Conditions of Natural Resources in the Study Area.”

Where are state highways located within the study area?

We focus our efforts on a series of proposed transportation projects located along SR-167 in King and Pierce Counties, Washington. The projects extend from the intersection with I-405 in the City of Renton, south on SR-167 to the Puyallup interchange. It crosses portions of the Green / Duwamish watershed and the watershed of the Puyallup River. The Green / Duwamish watershed is WRIA 9 and the Puyallup / White watershed is WRIA 10.

While we focus on projects in the SR-167 corridors, many other state highways in or near the study area could use and benefit from this watershed characterization and the lists of prioritized potential mitigation sites developed. These highways include segments of I-5 and I-405 and all or parts of State Routes 18, 161, 162, 164, 165, 169, 181, 410, 512, 515, 516, and 900.

Limited data exist on current and future project area boundaries. In lieu of actual right-of-way data, we estimated a project area for the purpose of analyzing potential project impacts for our watershed characterization work. We use the term “project area” throughout this document and its appendices to refer to the highway and its surrounding right-of-way area. The estimated project area boundaries were used to analyze potential project impacts and are not intended for use at a design level of analysis.

III. Conditions of Natural Resources in the Study Area

In this chapter we summarize conditions of natural resources and ecological processes found within the 18 subbasins we analyzed in our study area. For maps of the study area and subbasins, see Figure 39, Study Area Base Map, and Figure 40, Subbasins Used in Analysis. This information provides the landscape context for assessing each candidate mitigation site's potential to maximize environmental benefits. More detail on landscape features and conditions may be found in the Appendices.

First, we summarize conditions in the study area as a whole. Then we give a greater level of detail in the individual sections on each of the subbasins, where we present a characterization of resources in the individual subbasins of the study area (see Figure 40, Subbasins Used in Analysis). A certain amount of repetitiveness occurs in these characterizations, reflecting the similarity in landscape features across the study area.

What overall conditions did we find in the study area?

The study area totals about 222,500 acres – a little less than 350 square miles - and includes portions of the Green / Duwamish and Puyallup / White drainages. The study area portions of the Green River drainage (in WRIA 9) total about 117,800 acres. Tributaries to the Green River that are entirely or partially in the study area include the Black River system, Mill Creek, the Soos Creek system, and Newaukum Creek. The study area portions of the Puyallup River drainage (in WRIA 10) total about 104,700 acres. Tributaries to the Puyallup River that are entirely or partially in the study area include the White River, the Carbon River, South Prairie Creek, and Fennell Creek.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest. Oak woodland/prairie occurred on well-drained upland outwash deposits in a very few locations in the southwest portion of the study area.

Current conditions

Current land use in the study area varies widely (see Figure 2, Current Land Cover in the Study Area). Figure 42 is a map of current land cover in the study area, based on 1998 Landsat data.

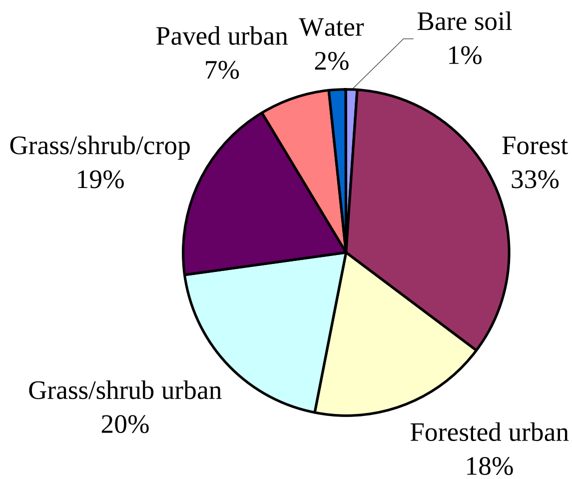
Figure 1: Green River at Flaming Geyser State Park.

In WRIA 9, dense industrial and commercial development covers historical flood-plain areas on the lower Green River valley floor. Remnant pasture and farmland can still be found along the Green River near Mill Creek. Upstream of Auburn the Green River floodplains become more rural, and are covered by mixed deciduous forest and pasture (Figure 1, Green River at Flaming Geyser State Park).

In WRIA 10, dense industrial and commercial development occurs in the Puyallup Valley within the cities of Puyallup and Sumner, and in the White River Valley within the cities of Sumner and Auburn. Outside of these areas, land use in the valleys transitions to mixed residential and agriculture. Above Auburn, the White River Valley flows in a moderately- to tightly-confined gorge, and is covered by mixed deciduous-conifer forest.

Land cover on the upland plateaus transitions from intense uses in the west to forest in the east. Mixed residential and commercial uses predominate on the Federal Way uplands, the Lake Tapps uplands, and the western half of the Soos Creek subbasin. The Newaukum Creek subbasin on the Enumclaw plateau contains the highest concentration of agricultural lands. Forested areas in the Green River watershed are concentrated along tributary stream valleys and in the Covington Creek subbasin. Forest also predominates in upland portions of the South Prairie Creek and lower Carbon River subbasins. Floodplains in these two subbasins have been converted to agriculture, with residential and urban development in and around the town of Orting.

Urban land covers 44 percent of the study area, corresponding to a total impervious area (TIA) of 31 percent. Non-urban forest covers 34 percent of the study area. Most of this forest consists of managed timberlands on the upland plateaus and relatively young stands of mixed deciduous trees on the valley floors.



Land cover data from 1998 Landsat images.

Figure 2. Current Land Use in the Study Area.

Future conditions

We estimated future conditions in the study area based on the comprehensive plans of cities and counties. See Figure 43, Future Land Cover / Land Use in the Study Area for more detail. Overall, we estimated that the current TIA of 31 percent for the whole study area will increase to about 39 percent TIA.

The more urban parts of the study area are already close to build-out conditions and will see only minor increases of commercial, industrial, and residential development, and correspondingly small increases in the already high TIA percentages. Suburban areas will see moderate increases in commercial, industrial, and residential development, and moderate increases in TIA. Some of the currently rural areas will have sharp increases in development and correspondingly major increases in TIA.

Three subbasins, Lower Carbon River (with an 84 percent increase in TIA), Middle Green River (with a 59 percent increase in TIA), and Covington Creek (with an 56 percent increase in TIA) are especially likely to see major land use change.

Hydrogeology and groundwater recharge

The study area is made up of four upland plateaus (Federal Way, Covington, Enumclaw, and Lake Tapps) separated by river valleys. Alluvial sediments 40 to 300 feet thick cover the major river valleys. Thick sequences of glacial sediments form the plateaus, beginning with glacial till that has been compressed into hardpan by the Pleistocene ice sheets (see Figure 44, Surficial Geology in the Study Area) The till covers sands and gravels deposited by melt water from advancing glaciers (advance outwash). Melt water deposits from receding glaciers (recessional outwash) often cover stream valleys. Groundwater recharge is greatest where outwash deposits are exposed at the surface (Vacarro et al., 1998).

The Osceola mudflow arose from an eruption on Mount Rainier 5,000 years ago, and covered glacial deposits on the Enumclaw plateau. Mudflow deposits are made up of relatively impermeable clays and debris.

Figure 45, Groundwater Flow in the Study Area, shows the dominant groundwater flow directions. The major river valleys contain an unconfined alluvial aquifer that is connected to the Green and White rivers. Water in this aquifer flows down the Green and White valleys, towards the Duwamish and Puyallup rivers. Some groundwater still flows from the White River into the Green River, roughly following the historic alignment of the White River before it was diverted in the early 1900s (Pacific Groundwater Group, 1999).

The alluvial aquifer covers sands that were deposited as a delta by glacial melt water from the Green and White rivers. These coarse sands now make up an important aquifer used by the City of Auburn for water supply (Pacific Groundwater Group, 1999). This aquifer is often separated from the alluvial aquifer by layers of mudflow deposits.

Coarse advance outwash and pre-Fraser deposits make up the most important aquifers on the upland plateaus. Groundwater within these aquifers flows towards stream valleys, and often emerges as springs and seepage zones on the bluffs that line the Green, Puyallup, and White river valleys (Woodward et al., 1995). These seepage zones are an important source of recharge for the alluvial aquifers in the Green and White river valleys (Pacific Groundwater Group, 1999).

Figure 46, Sole Source Aquifers / Critical Aquifer Recharge Areas, shows the sole source aquifers and Critical Aquifer Recharge Areas (CARAs) in the study area. Most of the King County portion of the study area is in the South King County Groundwater Management Area. King County designates CARAs as “High CARAs” to protect water quality when they overlie aquifers that are most vulnerable to contamination, generally shallow water table aquifers with rapid infiltration rates. King County has designated High CARAs in the Green and White alluvial aquifers. High CARAs are also designated in recessional outwash deposits in the Big Soos, Jenkins, and Covington subbasins. Pierce County designates CARAs to protect shallow alluvial aquifers in the White and Puyallup River valleys. The Central Pierce County Sole Source Aquifer abuts the southern study area boundary, and covers portions of the Mid Puyallup subbasin.

Runoff and streamflow

Historically, much of the runoff in the study area began as shallow subsurface flow through glacial till and recessional outwash deposits. Runoff response would have been slow until groundwater levels in the stream valleys rose to the surface. Once this occurred, streamflows would rise rapidly as runoff began to flow over saturated soils. Most of the annual flow volume in these streams would have been derived from groundwater.

Mudflow (lahar) deposits on the Enumclaw plateau are relatively impermeable, and would have generated runoff more rapidly. However, these deposits historically contained extensive depressional wetlands that would have delayed runoff to streams. Most of these wetlands have been drained and cleared for agriculture, resulting in increased stormwater runoff, flooding, and erosion in Newaukum Creek and other mudflow drainages.

Development and land clearing have significantly changed how water is delivered to streams. Impervious surfaces now cover 31 percent of the study area. These paved and compacted surfaces convert rainfall to overland flow that is often routed directly into streams through storm drains and ditches. These impacts are especially acute in groundwater-dominated streams like Soos Creek. King County estimates that development may increase peak flows by as much as 3.5 times in catchments dominated by outwash deposits (Kerwin and Nelson, 2000). This conversion of groundwater flow to surface runoff also decreases dry-season base flows, which in turn degrades fish habitat, water supply, and water quality. Recessional outwash and coarse glacial drift deposits cover 23 percent of the study area.

Fine-grained alluvial soils on the Green, White, and Puyallup valley floors saturate quickly, but most local runoff would historically have been captured in extensive floodplain wetlands. During major storms most of the valley floor would have been inundated by overbank flows from the Green, White, and Puyallup Rivers. Currently, overbank flooding in these rivers has been substantially reduced or eliminated by large flood control dams (Howard Hansen Dam on the Green River and Mud Mountain Dam on the White River) and an extensive system of levees. The river valleys below Auburn have been covered by intense urban land uses, much of which is built on fill within historical wetlands and floodplains. Flooding on the valley floors is now driven primarily by groundwater flooding in the remaining wetlands and topographic depressions.

The flows in a 22-mile reach of the White River between Buckley and Sumner are impacted by the Lake Tapps diversion and hydroelectric project. This project has diverted up to 2,000 cfs from the river, leaving as little as 130 cfs (30 cfs prior to 1986) in the reach during most times of the year, with documented adverse impacts to both water quality and fish.

Wetlands

We subdivided the study area into four distinct lithotopo units as well as into the subbasins for characterizing wetland resources. Based on hydric soils and existing wetlands, we estimate that wetlands made up over 25 percent of the study area prior to European settlement. We further estimate that slightly less than one half (47 percent or 27,380 acres) of the pre-development wetlands (57,696 acres) in the study area currently exist or have wetland restoration potential. Of the wetlands that remain or have restoration potential, we found that approximately one-third (32 percent or 15 percent of pre-development wetland resources) have little or no hydrologic or vegetative alteration. The remaining two-thirds of all current or potential wetlands have some evidence of alteration, based on aerial photo interpretation.

Riparian condition

The SR-167 study area contains a significant amount of riparian area, defined as a 67-meter buffer on either side of the stream. Riparian forest in the study area has been reduced by almost 50 percent. This is mainly due to urban development on the floodplains of the Green, White, and Puyallup River valleys, and agricultural use on the Enumclaw Plateau. Most of the remaining forest exists on hill slopes and riverine canyons.

Floodplain Condition

The principal floodplains of the study area lie along the Green River (including Mill Creek and the Black River), Puyallup, Carbon (including South Prairie Creek), and White Rivers. Floodplains are generally studied and managed at the river basin or county scale. The floodplains within the study area were characterized in this context; however, loss of historic floodplains were calculated by subbasin for the purposes of this report. The predominant characteristic of the floodplains in each of these drainages is that they have been greatly reduced from their original size due to land use patterns that began with timber harvesting and farming, shifting more recently to commercial and residential development. This development has in each case been facilitated by the installation of large flood control works including dams, levees, channel diversions, and headworks.

Water quality

The four pollutant categories that were modeled in this effort (nutrients, sediments, toxicants, and bacteria) display similarities in spatial distribution, but with several important nuances.

For the movement of nutrients, two large major areas of unusually high phosphorus loadings – “hotspots” – were observed. The largest of the nutrient hotspots covers the entire Kent Valley north from I-405 to the southern limits of the City of Auburn. This large contiguous area consists of major urbanized and industrialized landscapes interrupted by wetlands and farmland. The urban and agricultural land cover combined with low-permeability alluvial and altered urban soils results in uniformly high nutrient loadings. The second major hotspot for nutrients covers the northeasternmost portion of the Lower White River East Subbasin and the westernmost half of the Newaukum Subbasin. While urbanization in this area, near the towns of Buckley and Enumclaw, is not particularly intense, the very low permeability mudflow deposits in the area combined with extensive agricultural land cover resulted in high nutrient export loadings.

For the movement of sediments in the study area, only one major hotspot is observed, the Kent Valley area between Auburn and I-405. Three minor hotspots are also in the study area: the Enumclaw/Buckley mudflow area, areas near the confluence of the White and Puyallup rivers, and DAU 108 in the Middle Puyallup River South Subbasin.

For the movement of toxicants in the study area, only one hotspot area is apparent. Once again this is the Kent Valley, centered on downtown Auburn and the Kent downtown/warehouse district. No other areas of elevated toxicant levels were modeled in the study area.

The movement of bacteria in the study area had a different pattern. Unlike the other pollutant categories, elevated loading levels for bacteria are distributed widely throughout the study area. The only areas that do not exhibit relatively high bacteria loading levels are in the heavily forested region centered on the Jenkins, Covington, and Middle Green River subbasins and the Bonney Lake highlands region centered on the Fennel Creek, Lower Carbon, and South Prairie Creek subbasins.

Fish resources

Chinook, coho, steelhead, pink, sockeye, bull trout and cutthroat spend one or more parts of their life cycle within the study area. Chinook, pink, and sockeye salmon, as well as bull trout are found primarily in the mainstem rivers (Puyallup, White, Black, Carbon, Green) and larger tributaries. Coho, steelhead, and cutthroat utilize these tributaries as well, though will generally penetrate farther upstream; coho and cutthroat also utilize numerous smaller tributaries.

Human alteration to the movement of water

We characterized the effects of human land use on the natural delivery of water in the study area using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the western one-third of the study area, which includes the SR-167 corridor and surrounding Green, White, and Puyallup River floodplains, is in a “not properly functioning” condition for the delivery of water. This large area of DAUs, considered to be “not properly functioning,” also extends eastward through the Soos Creek and Jenkins Creek subbasins (the Covington area) and into the Lake Tapps and Fennel Creek subbasins (the Lake Tapps and Bonney Lake areas), with smaller isolated areas associated with the towns of Buckley, Enumclaw, and Black Diamond (Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

We characterized the effects of human land use on the natural delivery of sediment in the study area using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that nearly the entire study area is considered to be in an “at risk” condition for the delivery of sediment. Exceptions include four out of 238 DAUs considered to be “not properly functioning” and five considered to be “properly functioning” (Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

We characterized the effects of human land use on the natural delivery of large wood in the study area using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that nearly the entire SR-167 corridor and the associated Green and White River floodplains are considered to be in a “not properly functioning” condition for the delivery and routing of large wood. In addition, the Lake Tapps, Fennel Creek, Soos Creek, and Newaukum subbasins have 50 percent or more of their DAUs in a “not properly functioning” condition. In contrast, subbasins considered to be in the best landscape condition for the delivery and routing of wood include the Lower Carbon Subbasin having all DAUs in an “at risk” condition and the South Prairie Creek Subbasin having six DAUs in an “at risk” condition and two DAUs in a “properly functioning” condition (Figure 55, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

We characterized the effects of human land use on aquatic integrity in the study area using the following landscape attributes: percent riparian forest, percent TIA, and available Benthic – Index of Biological Integrity (B-IBI) scores at the DAU scale. Results indicate that nearly all of the SR-167 corridor and associated Green, White, and Puyallup River floodplains are considered to be in a “not properly functioning” condition for aquatic integrity. In addition, the Lake Tapps, Fennel Creek, Lower Green East, and Jenkins Creek subbasins have 50 percent or more of their DAUs in a “not properly functioning” condition. All remaining subbasins have a preponderance of DAUs in an “at risk” condition for aquatic integrity (Figure 56, “Condition for Aquatic Integrity”).

Upland forest cover

Upland forest cover in the study area has also been heavily influenced by human development. According to 1998 Landsat satellite imagery, only 34 percent of the landscape is composed of forest cover. Most of the remaining forest cover resides on hill slopes and river canyons, such as the headwaters of Newaukum Creek, or in the Green and White River canyons. The rest of the remaining forested areas are fragmented and widely distributed (Figure 59, “Final Condition Map for Forest Density”).

What conditions did we find in the Black River Subbasin?

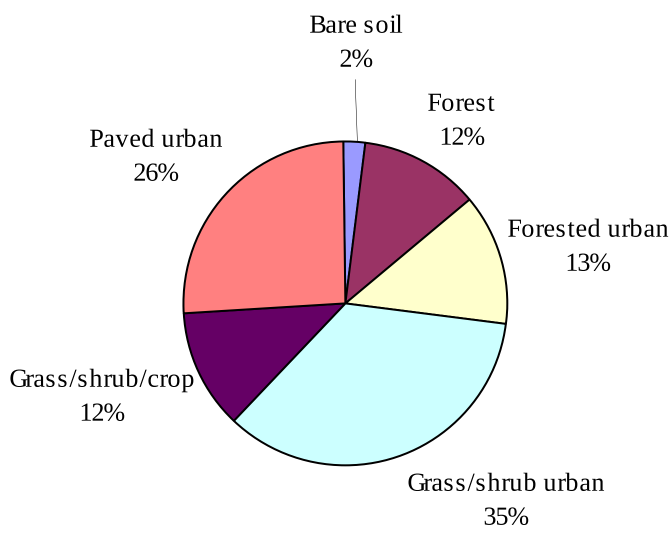
The Black River Subbasin drains 17,031 acres. Springbrook Creek flows into the remnant Black River channel, and enters the Green River through the Black River Pumping Station (see Figure 4, Black River Subbasin). Tributaries include Mill Creek (Kent), Garrison Creek, and Panther Creek.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plains, most of the hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

The Black River Subbasin is one of the most developed areas in the Green River watershed, with 74 percent urban land cover (see Figure 3, Current Land Use in the Black River Subbasin). Intense commercial and industrial land uses cover most of the valley floor. Residential uses cover headwater areas on the Covington uplands. The remaining forest is concentrated in stream valleys and ravines that flow down from the Covington uplands into Springbrook Creek.



Land cover data from 1998 Landsat images.

Figure 3. Current Land Use in the Black River Subbasin.

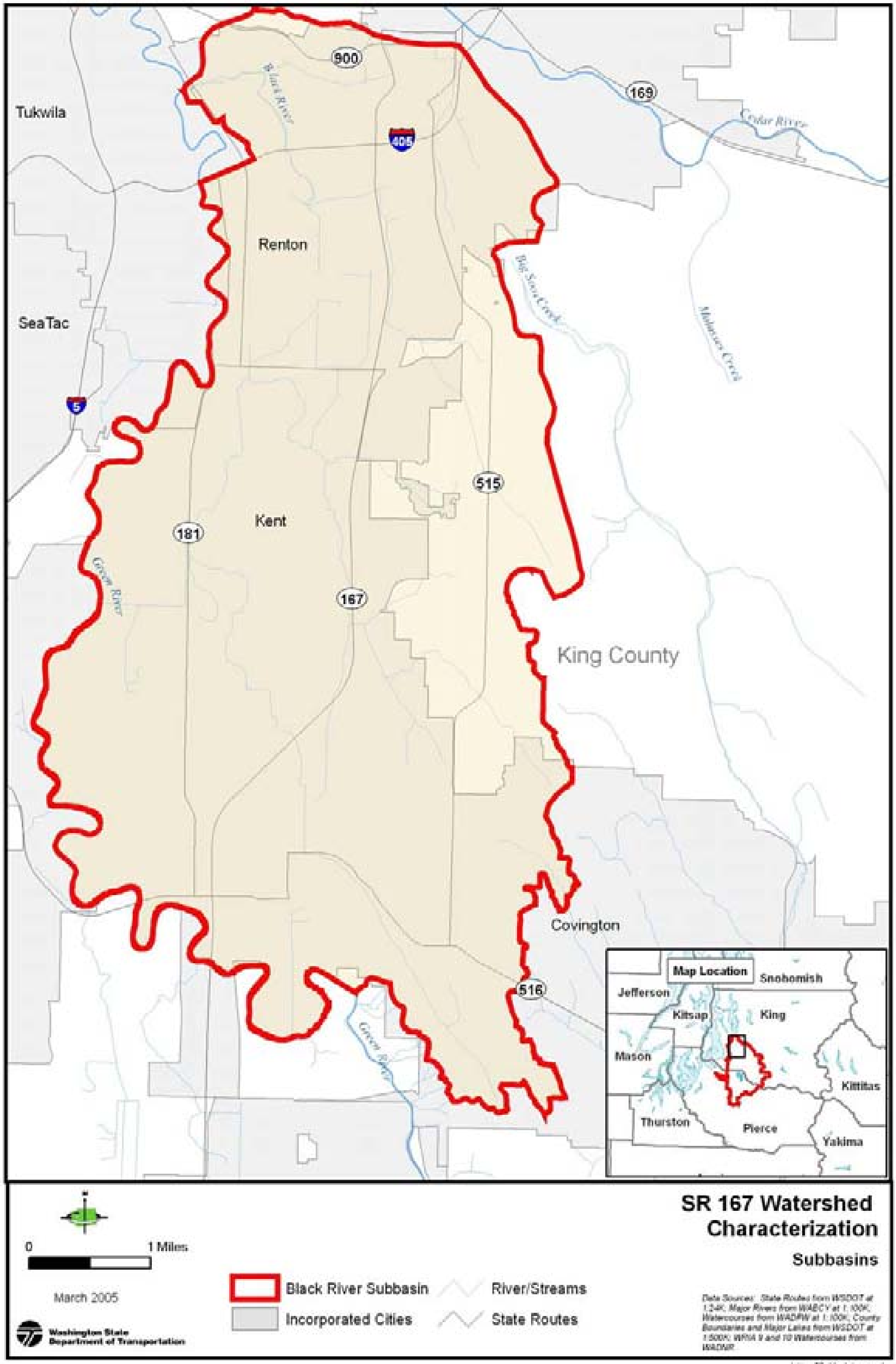


Figure 4. Black River Subbasin.

Future conditions

Future land use in the Black River Subbasin is predicted to remain similar to existing land use, with infill increasing the TIA from 58 percent to 65 percent.

Hydrogeology and groundwater recharge

Mill Creek, Garrison Creek, and Panther Creek begin on the Covington Uplands, and cut ravines through glacial deposits before emerging onto the valley floor of the Green River. Recessional outwash deposits cover these ravines, and form small alluvial fans where the creeks transition onto the valley floor. Seepage zones emerge on the bluffs along the eastern valley wall, feeding wetlands and streams that line the upslope side of SR-167.

Springbrook Creek flows through alluvial floodplain deposits on the Green River valley floor. Infiltrated rainfall and seepage from outwash aquifers on the Covington Uplands recharges the alluvial aquifer. King County has designated most of the valley floor as a High Critical Aquifer Recharge Area, because of the vulnerability of the shallow alluvial aquifer to contamination. Coarse recessional outwash deposits line the margins of the valley and provide high rates of groundwater recharge. However, these occupy only three percent of the total subbasin area.

Runoff and streamflow

Mill, Garrison and other eastern tributaries arise from wetlands, lakes and rolling hills on the Covington Uplands, about 500 feet above the valley floor. Under natural conditions runoff in these till-covered areas would have been produced as shallow subsurface interflow. Most of the lower basin (including most of Springbrook Creek) would have been flooded by overbank flows from the Green River. Extensive wetlands would have occupied depressions within the fine-grained alluvial soils.

The watershed is now heavily urbanized, with a TIA of 58 percent. Most reaches of Mill, Garrison, and Springbrook Creeks have been extensively channelized. The Earthworks Park Detention Pond stores flood flows from upper Mill Creek. The Mill Creek diversion structure diverts flow from Mill Creek into the Green River Natural Resource Enhancement Area, which consists of a serious of storage cells connected by adjustable weirs (Aqua Terra Consultants, 2003).

Levees and dam operations have eliminated overbank flooding from the Green River, and flooding on the valley floor is now driven by high groundwater levels in topographic depressions (Federal Emergency Management Agency, 1989). During floods the Green River is perched above groundwater, preventing subsurface drainage to the river.

Outflows from the subbasin are controlled by the Black River Pumping Station. During floods the pumping station acts as a dam, preventing the Green River from backwatering into the Black River. During large floods, flows from Springbrook Creek exceed the capacity of the pumps, resulting in some backwater flooding along lower Springbrook Creek (Federal Emergency Management Agency, 1989).

Wetlands

Prior to human alteration, wetlands in the Black River Subbasin totaled approximately 4,527 acres and represented 27 percent of the subbasin. Of this pre-development total, we estimate that all 4,527 acres were wetlands. No natural deep-water lakes were noted. We estimate that approximately 1,090 acres, or six percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Twenty-four percent of the original 4,527 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 178 acres of wetlands in the Black River Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 16 percent of all existing or potential wetlands (1,090 acres) and four percent of all historic wetlands (4,527 acres). Seventy-six percent (825 acres) of the 1,090 acres of current or potential wetlands have evidence of hydrologic alteration, while 71 percent (772 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 911 acres (84 percent) of the 1,090 current or potential wetland acres in the Black River Subbasin are considered altered.

Of the 1,090 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Black River Subbasin include 909 acres of depressional wetlands (83 percent) and 164 acres of riverine wetlands (15 percent). Anadromous fish are estimated to have access to 48 percent (526 acres) of the 1,090 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development in the valley has encroached on almost all of the 67-meter wide riparian corridors in the Black River basin, but some forested areas remain (Figure 47, Condition of Riparian Systems by Subbasin). Only 26 percent of the riparian zone remains forested (646 acres of 2,507 total acres), and road crossings have disconnected many of these areas. Most of the remaining riparian forest lies along the eastern hill slope. Of the non-forested riparian corridor, 42 areas comprising 350 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The Black River once flowed from Lake Washington. It was decoupled from the lake in 1916, when lake levels were lowered by 11 feet in the course of constructing the Lake Washington Ship Canal and Ballard Locks. Today, the Black River Pumping Station pumps the flow of the Black River into the Green River, which subsequently flows into the Duwamish River. While no significant floods have occurred upstream of the pumping station, the Federal Emergency Management Agency (FEMA) flood study notes that the peak input flows from Springbrook Creek significantly exceed the firm capacity of the pump station, indicating the possibility of future flooding problems in this area (Federal Emergency Management Agency, 1989).

Water quality

The Black River Subbasin is one of the two most impacted parts of the study area due to water quality impairments (the other being Mill Creek). The Black River Subbasin has large contiguous areas of impervious cover resulting from the Kent warehouse and downtown districts. Soils in this subbasin consists primarily of alluvium, glacial till, and large expanses of “unclassified” urban soils, which are typically heavily re-worked and compacted. The subbasin has historically possessed a significant number of hazardous waste generators. Urbanization is heavy, soils are tight, and water tables are shallow, causing high runoff rates and resulting high pollutant entrainment. Several highways, including SR-167, SR-181 (West Valley Highway), and SR-515 (East Valley Highway) all contribute runoff and pollutants to the Black River Subbasin. State highways had significant (greater than 10 percent) contributions to non point source loadings in DAUs 35, 91, and 105, but relatively minor contributions (less than 4 percent) in DAUs 61, 175, 178, and 190. State highways did not contribute loadings to the other DAUs in the Black River Subbasin.

Fish resources

Chinook, coho, steelhead, and cutthroat spend one or more parts of their life cycle in this subbasin. Chinook are found in the Black River and Springbrook Creek; coho, steelhead, and cutthroat will generally penetrate farther upstream; coho and cutthroat also utilize several smaller, unnamed tributaries.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Black River and its tributaries in the Black River Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the entire Black River Subbasin is in a “not properly functioning” condition for the delivery of water (Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Black River and its tributaries in the Black River Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Black River Subbasin is considered to be in an “at risk” condition for the delivery of sediment (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Black River and its tributaries in the Black River Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the

Black River Subbasin is primarily in a “not properly functioning” condition for the delivery and routing of large wood. Exceptions include three DAUs east of SR-167 (Figure 54, “Condition of the Movement of Large Wood,” and Figure 55, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Black River and its tributaries in the Black River Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that nearly all of the Black River Subbasin is in a “not properly functioning” condition for aquatic integrity. The lone exception is a DAU in the east-central part of the subbasin considered to be in an “at risk” condition (Figure 56, “Condition of Aquatic Integrity,” and Figure 57, “Overall Condition of Aquatic Integrity”).

Upland forest cover

Forest covers only 12 percent (2,016 total forested acres) of the Black River Subbasin, concentrated in small, scattered patches along the eastern valley wall (Figure 58, “Upland Forest Cover”). Most of the remaining forest lies along riparian corridors or on steep slopes, and the subbasin’s primary land cover is composed of dense urban and commercial areas. The Black River Subbasin is considered “not properly functioning” for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Covington Creek Subbasin?

Covington Creek drains 14,281 acres on the Covington Uplands, and flows into Soos Creek downstream of Jenkins Creek (see Figure 6, Covington Creek Subbasin). The creek begins at Lake Sawyer, near the City of Black Diamond.

Pre-development land cover

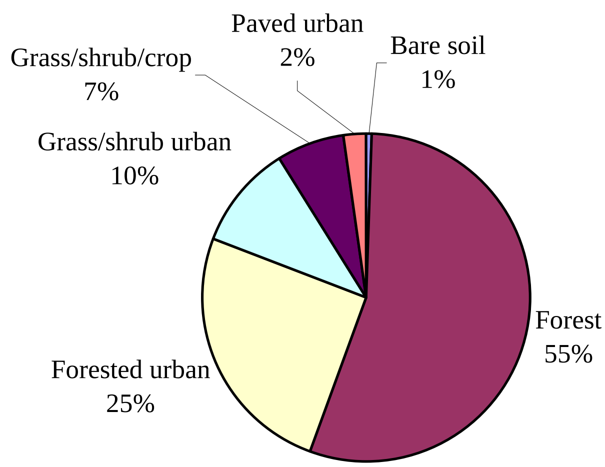
Prior to European settlement, coniferous forest covered most of the glacial drift plains, most of the hill slopes, and confined stream valleys in the Covington Creek Subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Covington Creek is the most rural part of the Soos Creek watershed, with 54 percent forest land cover (see Figure 5, Current Land Use in the Covington Creek Subbasin). Most of the stream valleys are forested, and large areas within the basin are managed for commercial timber production. Rural and low-density residential uses cover most other areas in the subbasin.

Future conditions

Future land use in the Covington Creek Subbasin is predicted to reflect a sharp increase in urban character, with residential and commercial development increasing the TIA from 22 percent to 34 percent, a 56 percent increase.



Land cover data from 1998 Landsat images.

Figure 5. Current Land Use in the Covington Creek Subbasin.

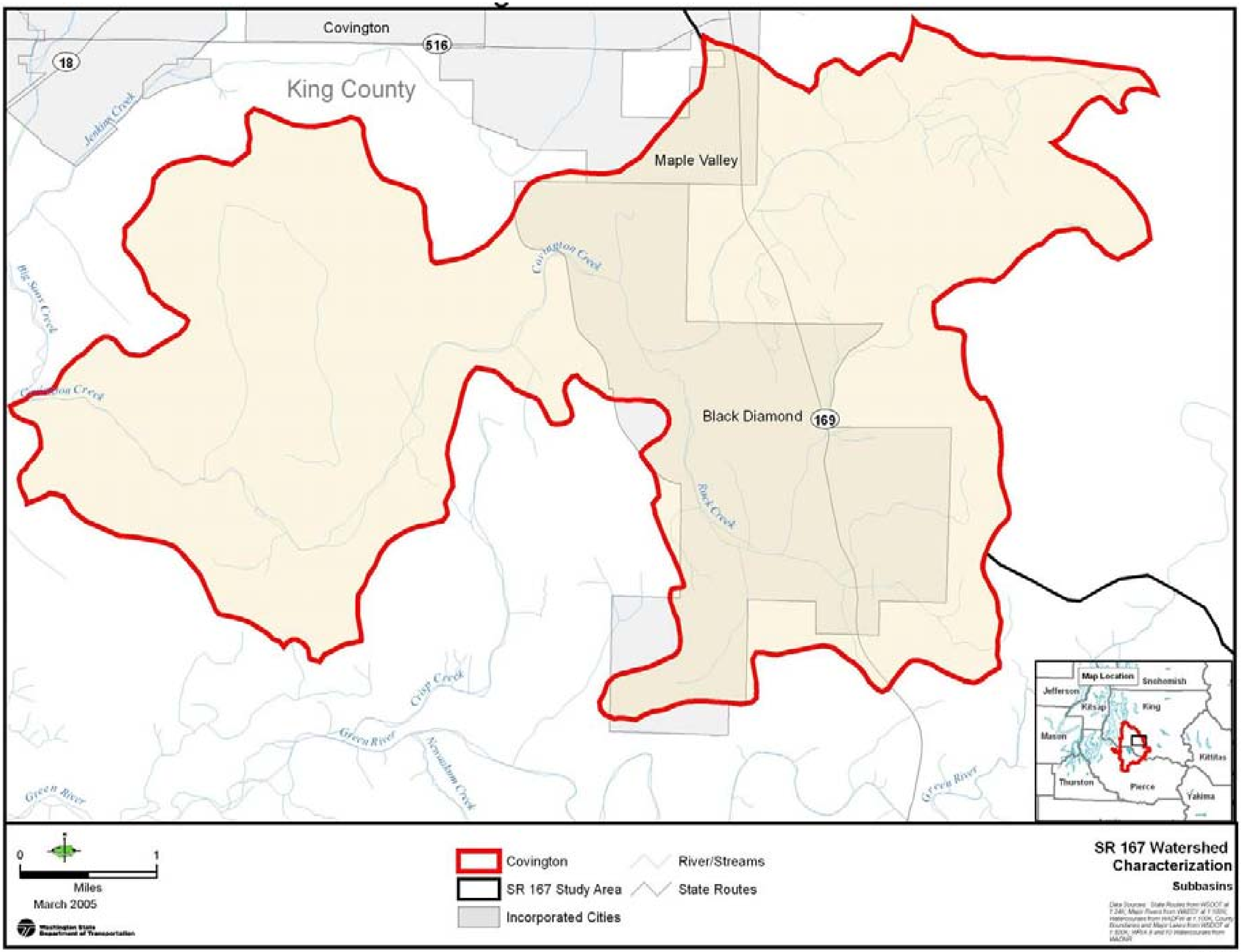


Figure 6. Covington Creek Subbasin.

Hydrogeology and groundwater recharge

Covington Creek drains glacial deposits on the Covington Uplands. Recessional outwash deposits cover 46 percent of the subbasin, and provide the highest rates of groundwater recharge. Groundwater is close to the surface in many of these areas, and is an important source of water for streams and valley bottom wetlands. Impervious surfaces now cover 29 percent of the recessional outwash deposits, reducing groundwater recharge and proportionally increasing surface runoff.

Advance outwash and pre-Fraser deposits make up the most important aquifers in the subbasin. King County designates High Critical Aquifer Recharge Areas in recessional outwash deposits in the Covington Creek valley, recognizing the vulnerability of shallow groundwater in these areas to contamination.

Runoff and streamflow

Shallow subsurface and groundwater flow through coarse recessional outwash deposits historically fed stream flows in the Covington Creek basin. Numerous lakes and valley bottom wetlands delayed runoff and provided flood storage. Covington Creek is dominated by groundwater flow, and is therefore highly sensitive to the hydrologic changes associated with urban development.

The subbasin is the most rural portion of the Soos Creek watershed, with a TIA of 21 percent. Much of this development has occurred on coarse soils that under natural conditions would have had high infiltration and low runoff rates. The Soos Creek Basin Plan estimates that with build-out land cover peak flows will increase by a factor of 3.5 in subbasins that are dominated by outwash deposits (Kerwin and Nelson, 2000).

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Covington Creek Subbasin totaled approximately 1,605 acres and represented 11 percent of the subbasin. Of this pre-development total, we estimate that 1,260 acres (nine percent of subbasin) were wetlands and 345 acres (two percent of subbasin) were natural deepwater lakes. We estimate that approximately 1,192 acres, or eight percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Ninety-five percent of the original 1,192 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 687 acres of wetlands in the Covington Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 58 percent of all existing or potential wetlands (1,192 acres) and 55 percent of all historic wetlands (1,260 acres). Forty-two percent (496 acres) of the 1,192 acres of current or potential wetlands have evidence of hydrologic alteration, while 13 percent (154 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 505 acres (42 percent) of the 1,192 current or potential wetland acres in the Covington Creek Subbasin are considered altered.

Of the 1,192 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Covington Creek Subbasin include 948 acres of depressional wetlands (80 percent) and 211 acres of riverine wetlands (18 percent). We estimate that anadromous fish have access to 58 percent (883 acres) of the 1,537 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on almost half of the 67-meter wide riparian corridors in the Covington Creek basin, but there are still significant forested areas (Figure 152, Condition of Riparian Systems by Subbasin). Of the 2,197 total acres, 58 percent, or 1,270 acres, of the riparian zone remain forested, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, 30 areas comprising 258 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of considerable size were evaluated in the Covington Creek Subbasin for this study. Potential restoration sites in floodplain areas for this subbasin were evaluated in terms of potential aquatic habitat, wetland, and/or riparian functions (see sections on wetlands and riparian).

Water quality

The Covington Creek subbasin showed the lowest levels of pollutant runoff in the study area for all four pollutant categories. This is a result of low levels of urbanization, highly pervious recessional outwash soils, and large contiguous tracts of forest land. Only one DAU (DAU 58) within the subbasin was found to be not properly functioning for water quality, located within Black Diamond city limits. SR-169 is the only state highway that contributes pollutants to the Covington Creek subbasin.

Fish resources

Chinook, coho, steelhead, and cutthroat spend one or more parts of their life cycle in this subbasin. Chinook are found only in Covington Creek; coho, steelhead, and cutthroat will generally penetrate farther upstream; coho and cutthroat also utilize several smaller, unnamed tributaries (RM 1.6, 2.5).

Human alteration to the movement of water

We calculated the effects of human land use on the natural delivery of water to the Covington Creek and its tributaries in the Covington Creek Subbasin using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Covington Creek Subbasin is primarily in an “at risk” condition, with 12 DAUs considered “at risk” for the movement of water and five DAUs, distributed throughout the subbasin, considered “not properly functioning”

(Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

We calculated the effects of human land use on the natural delivery of sediment to the Covington Creek and its tributaries in the Covington Creek Subbasin using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Covington Creek Subbasin is in an “at risk” condition for the delivery of sediment (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

We calculated the effects of human land use on the natural delivery and routing of large wood to the Covington Creek and its tributaries in the Covington Creek Subbasin using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Covington Creek Subbasin is a mix of DAUs in an “at risk” or a “not properly functioning” condition for the delivery and routing of large wood (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

We calculated the effects of human land use on aquatic integrity in the Covington Creek and its tributaries in the Covington Creek Subbasin using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Covington Creek Subbasin is predominantly in an “at risk” condition for aquatic integrity. Exceptions include six DAUs, distributed throughout the subbasin, considered to be in a “not properly functioning” condition (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 55 percent (7,712 total forested acres) of the Covington Creek Subbasin, including many contiguous patches leading from the study area boundary to the Green River (Figure 58, “Upland Forest Cover”). A few large patches of forest concentrated around the riparian areas contribute to the high level of upland forest connectivity in this subbasin. The Covington Creek Subbasin is considered “at risk” for upland forest cover due to scattered urban development and the medium-density distribution of forest in the subbasin (Figure 59, “Final Condition Map for Forest Density Areas”). This subbasin has a median probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape.

What conditions did we find in the Jenkins Creek Subbasin?

Jenkins Creek drains 10,189 acres on the Covington Uplands, and flows into Soos Creek upstream of Covington Creek (see Figure 8, Jenkins Creek Subbasin).

Pre-development land cover

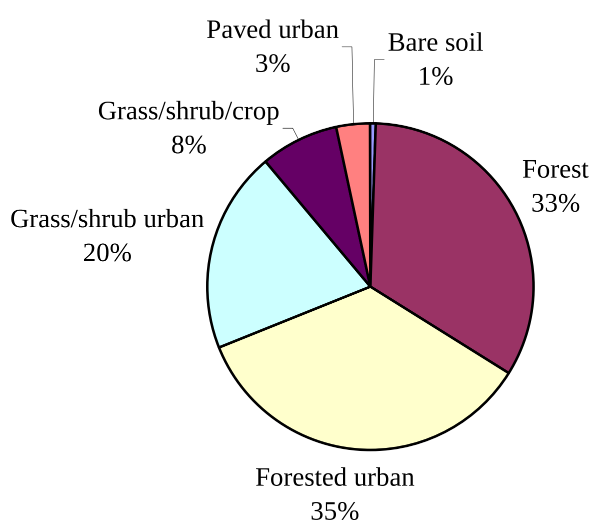
Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Like much of the Soos Creek watershed, the Jenkins Creek Subbasin is one of the most rapidly developing areas in King County (see Figure 7, Current Land Use in the Jenkins Creek Subbasin). Rural land uses still predominate, but are being converted to more intense residential uses. Portions of Jenkins Creek flow through the cities of Covington and Maple Valley, where suburban and urban land uses are expanding. Forested land is concentrated in wetland and riparian areas.

Future conditions

Future land use in the Jenkins Creek Subbasin is predicted to reflect a fairly strong increase in residential and commercial development, increasing the TIA from 33 percent to 44 percent, a 32 percent increase.



Land cover data from 1998 Landsat images.

Figure 7. Current Land Use in the Jenkins Creek Subbasin.

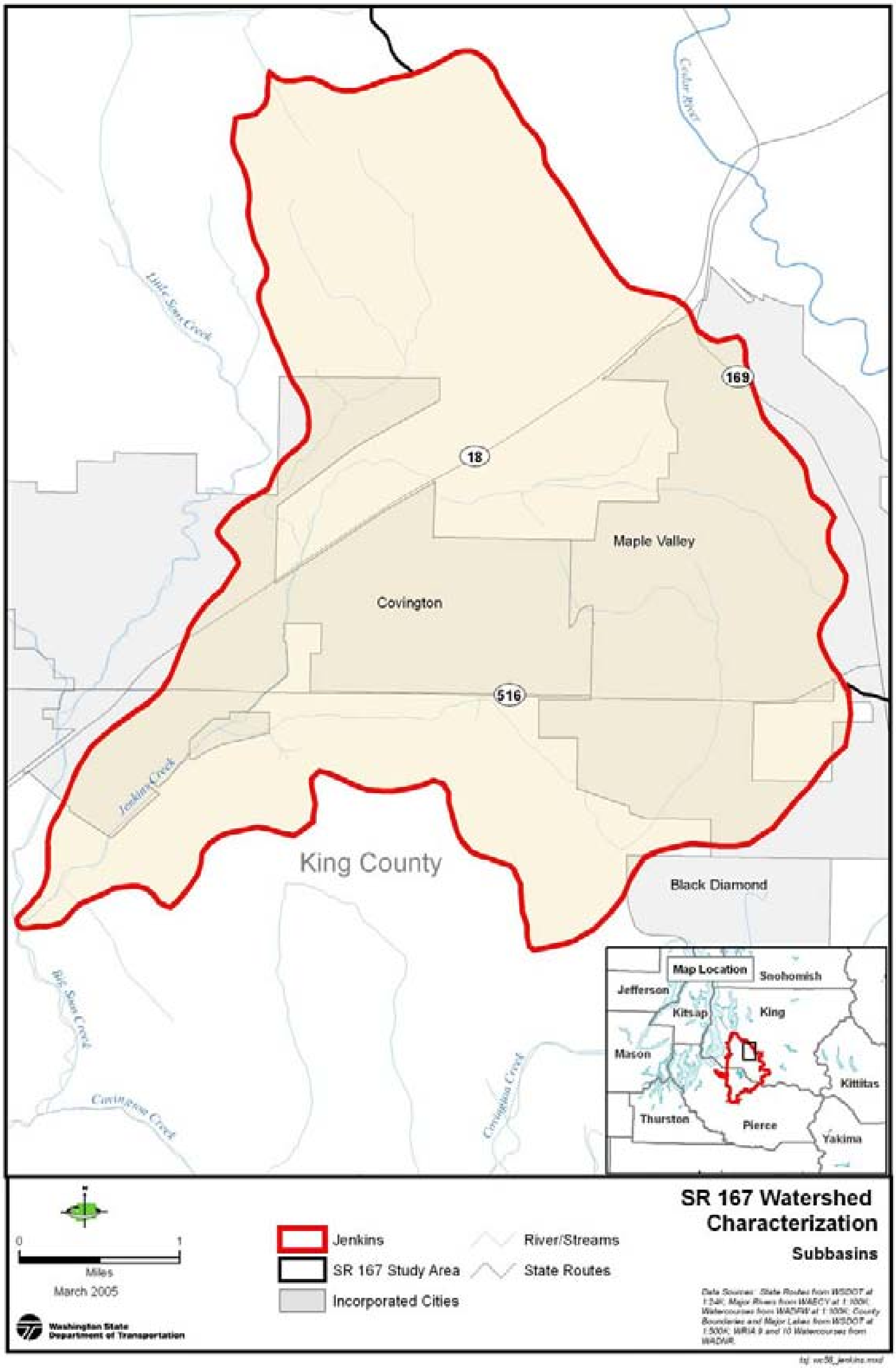


Figure 8. Jenkins Creek Subbasin.

Hydrogeology and groundwater recharge

Jenkins Creek drains glacial deposits on the Covington Uplands. Recessional outwash deposits cover 60 percent of the subbasin, and provide the highest rates of groundwater recharge. Groundwater is close to the surface in many of these areas, and is an important source of water for streams and valley bottom wetlands. Impervious surfaces now cover 39 percent of the recessional outwash deposits, reducing groundwater recharge and proportionally increasing surface runoff.

Advance outwash and pre-Fraser deposits make up the most important aquifers in the subbasin. King County designates High Critical Aquifer Recharge Areas in recessional outwash deposits in the Jenkins Creek valley, recognizing the vulnerability of shallow groundwater in these areas to contamination.

Runoff and streamflow

Shallow subsurface and groundwater flow through coarse recessional outwash deposits historically fed stream flows in the Jenkins Creek basin. Numerous lakes and valley bottom wetlands delayed runoff and provided flood storage. Jenkins Creek is dominated by groundwater flow, and is therefore highly sensitive to the hydrologic changes associated with urban development.

The subbasin is rapidly developing, and now has a TIA of 33 percent. Much of this development is happening on coarse soils that, under natural conditions, would have had high infiltration and low runoff rates. The Soos Creek Basin Plan estimates that, with build-out, land cover peak flows will increase by a factor of 3.5 in subbasins that are dominated by outwash deposits (Kerwin and Nelson, 2000).

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Jenkins Creek Subbasin totaled approximately 1,270 acres and represented 13 percent of the subbasin. Of this pre-development total, we estimate that 1,093 acres (11 percent of subbasin) were wetlands and 177 acres (two percent of subbasin) were natural deepwater lakes. We estimate that approximately 866 acres, or nine percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Seventy-nine percent of the original 1,093 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 606 acres of wetlands in the Jenkins Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 70 percent of all existing or potential wetlands (866 acres) and 56 percent of all historic wetlands (1093 acres). Twenty-seven percent (234 acres) of the 866 acres of current or potential wetlands have evidence of hydrologic alteration, while 27 percent (236 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 260 acres (30 percent) of the 866 current or potential wetland acres in the Jenkins Creek Subbasin are considered altered.

Of the 866 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Jenkins Creek Subbasin include 526 acres of depressional wetlands (61 percent) and 226 acres of riverine wetlands (26 percent). Anadromous fish are estimated to have access to 48 percent (499 acres) of the 1,043 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on much of the 67-meter wide riparian corridors in the Jenkins Creek basin, but there are still significant forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Of the 1,106 total acres, 59 percent, or 655 acres, of the riparian zone remain forested, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, six areas comprising 25 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of considerable size were evaluated in the Jenkins Creek Subbasin for this study. Potential restoration sites in floodplain areas for this subbasin were evaluated in terms of potential aquatic habitat, wetland, and/or riparian functions (see sections on wetlands and riparian).

Water quality

The Jenkins Creek Subbasin consists mostly of rural lands, low density residential areas, hobby farms, wetlands, lakes, and significant patches of second growth forests. The northern half of the subbasin consists mostly of glacial till soils, while the southern half is covered by predominantly high permeability recessional outwash soils. Runoff rates and loading rates are correspondingly lower in the southern DAUs within the subbasin. Like all of the Soos Creek watershed, the Jenkins Creek Subbasin is transitioning from rural land uses to residential land uses. SR-18 and SR-516 both contribute runoff and loadings to DAUs in the Jenkins Creek Subbasin.

Fish resources

Chinook, coho, steelhead, and cutthroat spend one or more parts of their life cycle in this subbasin. Chinook are found only in Covington Creek; coho, steelhead, and cutthroat generally penetrate farther upstream, and also utilize several smaller, unnamed tributaries (RM 2.0, RM 3.2).

Human alteration to the movement of water

We characterized the effects of human land use on the natural delivery of water to Jenkins Creek and its tributaries in the Jenkins Creek Subbasin using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Jenkins Creek Subbasin is predominantly in a "not properly functioning" condition for the delivery of water. The three northernmost DAUs are considered in an "at risk condition," while the remaining 12 DAUs to the south are "not properly functioning" (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

We characterized the effects of human land use on the natural delivery of sediment to Jenkins Creek and its tributaries in the Jenkins Creek Subbasin using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Jenkins Creek Subbasin is in an "at risk" condition for the delivery of sediment (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

We characterized the effects of human land use on the natural delivery and routing of large wood to the Jenkins Creek and its tributaries in the Jenkins Creek Subbasin using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Jenkins Creek Subbasin has a mix of condition ranks for the delivery and routing of large wood. Two DAUs are considered to be "properly functioning," seven DAUs are considered to be "at risk," and six DAUs are considered to be in a "not properly functioning" condition (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

We characterized the effects of human land use on aquatic integrity in the Jenkins Creek and its tributaries in the Jenkins Creek Subbasin using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Jenkins Creek Subbasin is primarily in a "not properly functioning" condition for aquatic integrity. Ten DAUs primarily in the southern and western part of the subbasin are considered to be "not properly functioning," while a group of four DAUs in the northern part of the subbasin and one DAU in the southwest are in an "at risk" condition (Figure 56, "Condition Map for Aquatic Integrity," and Figure 57, "Overall Condition map for Aquatic Integrity").

Upland forest cover

Forest covers 33 percent (3,329 total forested acres) of the Jenkins Creek Subbasin. Most of the remaining forest lies along riparian corridors, and there is a section in the northern part of the subbasin that is part of a larger forest complex around Lake Youngs in the Soos Creek Subbasin (Figure 58, "Upland Forest Cover"). Due to the otherwise widely dispersed forest cover in the Jenkins Creek Subbasin, it is considered "not properly functioning" for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, "Final Condition Map for Forest Density Areas").

What conditions did we find in the Lower Green East Subbasin?

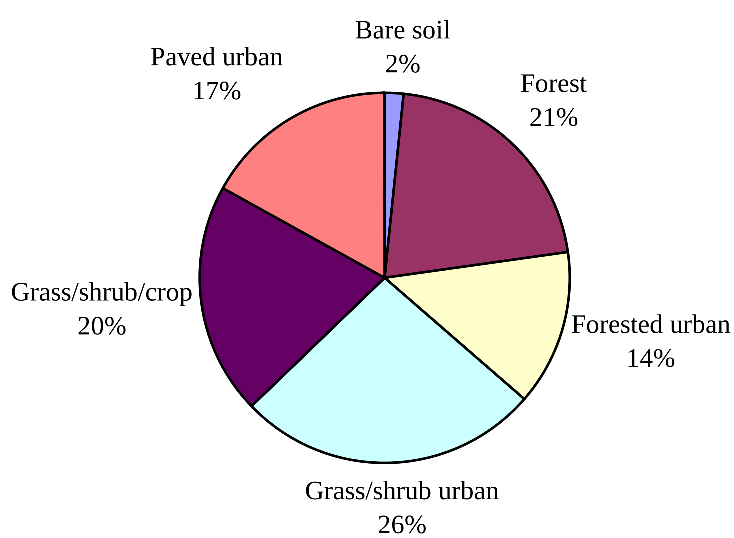
The eastern portion of the Lower Green Subbasin includes Lea Hill Creek, Olson Creek, Cobble Creek, and areas that drain directly to the Green River between Soos Creek and Mill Creek (see Figure 10, Lower Green East Subbasin). These streams drain a total of 4,787 acres.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Urban land uses cover 62 percent of this subbasin (see Figure 9, Current Land Use in the Lower Green East Subbasin). The headwaters of tributaries such as Lea Hill Creek, Olson Creek, and Cobble Creek are covered by residential and commercial development in the City of Kent. Forest is concentrated in parks along the Green River, and on the steep bluffs and tributary ravines that drain the Covington uplands.



Land cover data from 1998 Landsat images.

Figure 9. Current Land Use in the Lower Green East Subbasin.

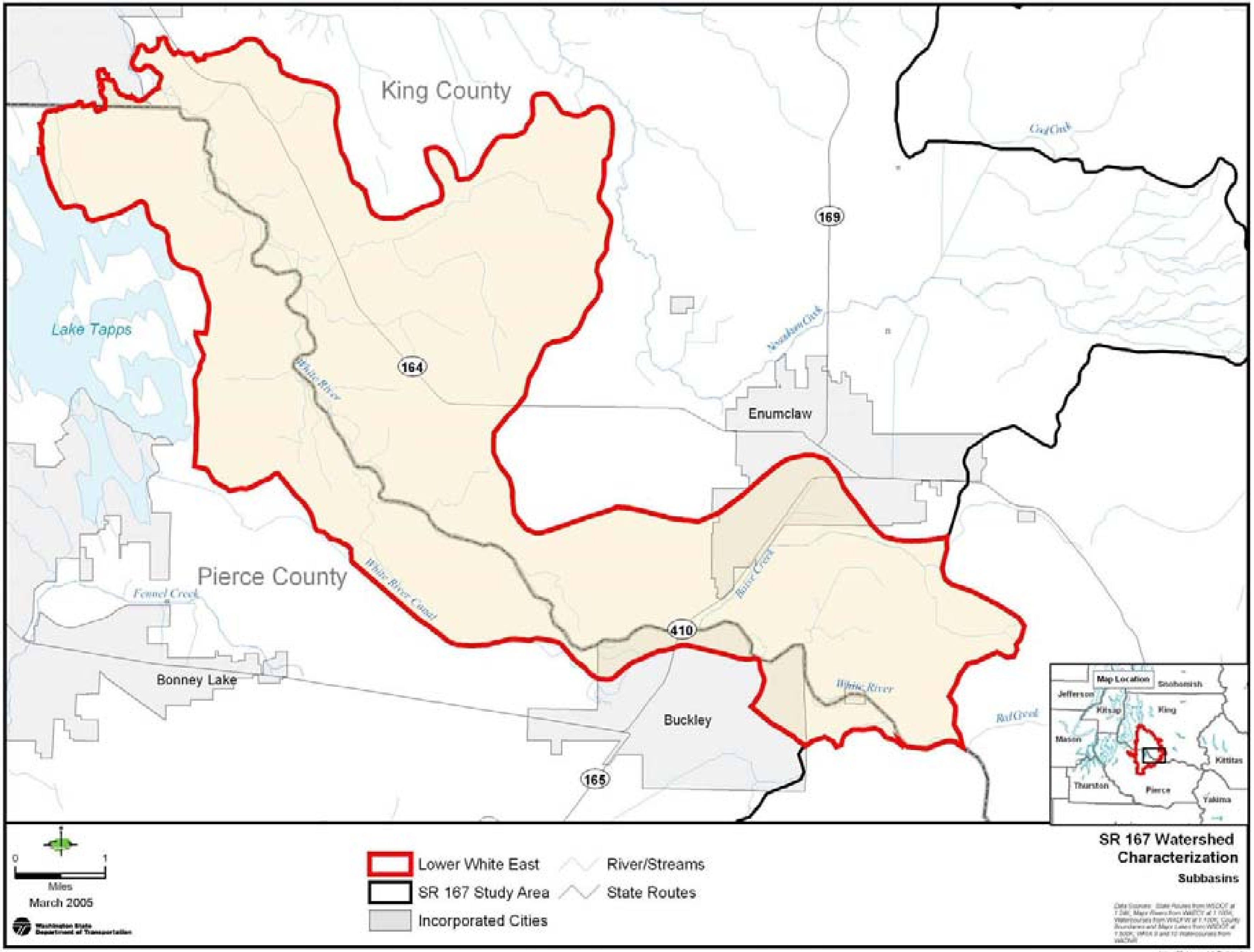


Figure 10. Lower Green East Subbasin.

Future conditions

Future land use in the Lower Green East Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 44 percent to 54 percent.

Hydrogeology and groundwater recharge

The Lower Green flows through extensive alluvial deposits on the valley floor. Tributaries arise from the Covington uplands, and cut steeply through ravines before emerging onto alluvial fans on the valley floor. Seepage zones line the edges of the valley where bluffs have exposed advance outwash and pre-Fraser deposits.

An extensive alluvial aquifer system occupies the lower Green valley. Alluvial deposits in the valley range from 40 to 300 feet thick. The alluvium is underlain by recessional delta sands and gravels that were deposited at the end of the last ice age (Pacific Groundwater Group, 1999). The alluvium and delta deposits combine into a single aquifer near Auburn, where the Middle Green and White River enter the Auburn-Kent valley. This aquifer is an important water source of the City of Auburn and other local community water systems. Some groundwater still flows from the White River into the Green River, roughly following the historic alignment of the White River before it was diverted into the Puyallup in the early 1900s (Pacific Groundwater Group, 1999).

Most of the recharge for the alluvial and recessional delta aquifer comes from seepage from outwash aquifers on the Covington and Federal Way Uplands. Recessional outwash terraces line the valley margins and provide high rates of recharge, but occupy only 12 percent of the total subbasin area. Fifty-three percent of these outwash deposits are now covered by impervious surfaces. King County has designated the entire Lower Green valley floor as a High Critical Aquifer Recharge Area.

Runoff and streamflow

Dams, diversions, and levees have drastically altered the hydrology of the Lower Green River. Howard Hanson Dam limits flows at Auburn to less than 12,000 cubic feet per second (cfs), which is equivalent to the pre-dam two-year flood. Levees and stream bank revetments affect over 80 percent of the length of channel between RM 25 and RM 31, and levees are virtually continuous along both banks downstream of RM 25 (Kerwin and Nelson, 2000). These alterations have effectively disconnected the Green River from its historical floodplain. Flooding on the valley floor is now caused primarily by high groundwater levels in topographic depressions and wetlands (Federal Emergency Management Agency, 1989).

The dam also augments summer flows to compensate for diversions by the City of Tacoma. However, the diversions still reduce the average seven-day low flow at Auburn by seven percent. Flows at Auburn have failed to meet the minimum instream flow requirements set by the Washington State Department of Ecology (Ecology) in 21 of the last 30 years (Kerwin and Nelson, 2000).

Historically the glacier-fed White River was an important source of cold water to the lower Green, and provided 75 percent of the river's coarse sediment. In the early 1900's a log jam diverted the entire White River into the Puyallup through an overflow channel formerly called the Stuck River. A diversion structure was constructed in 1911 to keep the White River in this configuration. The loss of flow from the glacier-fed White reduced summer flows in the Green by about 50 percent (Kerwin and Nelson, 2000). Groundwater still flows from the White to the Green, contributing about 56 cfs to the lower Green in the late summer (Pacific Groundwater Group, 1999).

Most of the subbasin is heavily developed, with a TIA of 44 percent. This has increased peak flows, erosion, and delivery of fine sediment in tributary streams. These hydrologic changes are substantial within tributaries, but have only minor impacts to the mainstem Green because of the overwhelming flow regime changes associated with diversions, channel modifications, and dam operations (Kerwin and Nelson, 2000).

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Lower Green East Subbasin totaled approximately 386 acres and represented eight percent of the subbasin. Of this pre-development total, we estimate that all 386 acres were wetlands. No natural deepwater lakes were noted. We estimate that approximately 164 acres, or three percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty-three percent of the original 386 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 69 acres of wetlands in the Lower Green East Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 42 percent of all existing or potential wetlands (164 acres) and 18 percent of all historic wetlands (386 acres). Forty-eight percent (79 acres) of the 164 acres of current or potential wetlands have evidence of hydrologic alteration, while 57 percent (93 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 95 acres (58 percent) of the 164 current or potential wetland acres in the Lower Green East Subbasin are considered altered.

Of the 164 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower Green East Subbasin include 130 acres of depressional wetlands (79 percent) and 34 acres of riverine wetlands (21 percent). Anadromous fish are estimated to have access to 14 percent (22 acres) of the 164 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the Lower Green River East basin, but there are still significant forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Sixty-eight percent of the riparian zone remains forested, or 1,839 acres of 2,938 total acres, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, however, only nine areas comprising 52 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The Green River valley has undergone dramatic changes in floodplain conditions since the 1800's, most notably construction of the Howard Hanson Dam in 1962. This project controls flood flows through the rest of the system limiting peak flow to 12,000 cfs. This is roughly equivalent to the two-year unregulated flow. In addition extensive levees have further de-coupled most of the floodplain from the Green River. As a result, much of it has been removed from floodplain jurisdictions for development.

Of 3,779 acres of original floodplain in the Lower Green river subbasins only 1,281 acres remain (these figures include the Lower Green West subbasin).

Water quality

The Lower Green River East Subbasin consists mostly of medium density residential neighborhoods, commercial development, and steep wooded bluffs adjacent to the Green River. Soils are predominantly glacial till soils. There are very few patches of undeveloped land in the Green River East subbasin, though densities are somewhat lower than in the highly urbanized areas of Kent or Auburn. Runoff volumes from non point sources tend to be relatively high, as is typical of landscapes dominated by residential land covers. No state highways contribute runoff or loads to the Lower Green River East subbasin.

Fish resources

Chinook, coho, steelhead, pink, sockeye, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. Chinook are found primarily in the mainstem Green and larger tributaries (Black River – reported below, Mill Creek – reported below). Coho, cutthroat and steelhead will utilize the same tributaries, though will generally penetrate farther upstream; in addition, coho and cutthroat utilize numerous smaller, unnamed tributaries. Pink salmon and sockeye are found in the mainstem Green.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Lower Green River and its tributaries in the Lower Green East Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Lower Green East Subbasin is primarily in a "not properly functioning" condition for the delivery of water. Exceptions include the three northernmost DAUs considered to be "at risk" for the movement of water (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Lower Green River and its tributaries in the Lower Green East Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Lower Green East Subbasin is in an “at risk” condition for the delivery of sediment (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Lower Green River and its tributaries in the Lower Green East Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Lower Green East Subbasin consists of DAUs in either an “at risk” or a “not properly functioning” condition for the delivery and routing of large wood. Specifically, the five northern DAUs are considered to be in an “at risk” condition and the two southern DAUs are considered “not properly functioning” (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Lower Green River and its tributaries in the Lower Green East Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Lower Green East Subbasin is a mix of DAUs considered either “at risk” or “not properly functioning” for aquatic integrity (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 21 percent (1,019 total forested acres) of the relatively small Lower Green River East Subbasin. Most of the remaining forest lies along riparian corridors, the Green River, and is concentrated in patches along the slopes of the valley wall (Figure 58, “Upland Forest Cover”). Due to the otherwise widely dispersed forest cover and minimal forest cover in the valley of the Lower Green River East Subbasin, it is considered “not properly functioning” for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Lower Green West Subbasin?

The Lower Green West Subbasin includes Mullen Slough and areas that drain directly to the Green River below Mill Creek (see Figure 12, Lower Green West Subbasin). These streams drain a total of 2,686 acres.

Pre-development land cover

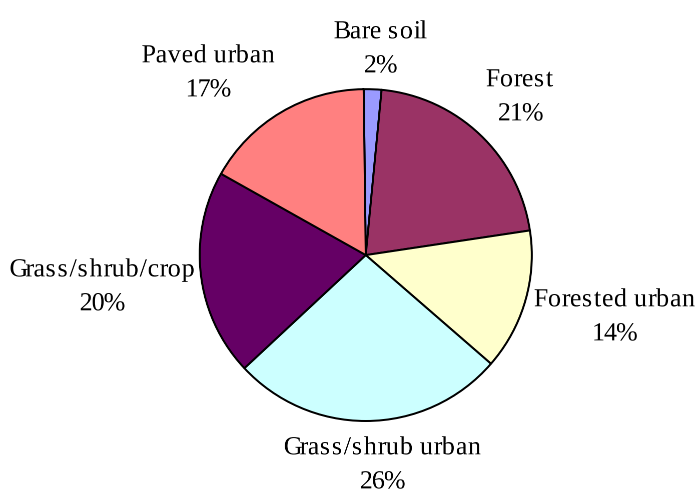
Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Nearly 50 percent of the subbasin is covered by urban land (see Figure 11, Current Land Use in the Lower Green West Subbasin). Thirty percent is covered by grass/shrub/crop vegetation, primarily in open wetland and floodplain areas on the valley floor and along Mullen Slough. The remaining forest is concentrated along the western margin of the valley, on the steep bluffs of the Federal Way uplands.

Future conditions

Future land use in the Lower Green West Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 41 percent to 46 percent.



Land cover data from 1998 Landsat images.

Figure 11. Current Land Use in the Lower Green West Subbasin.

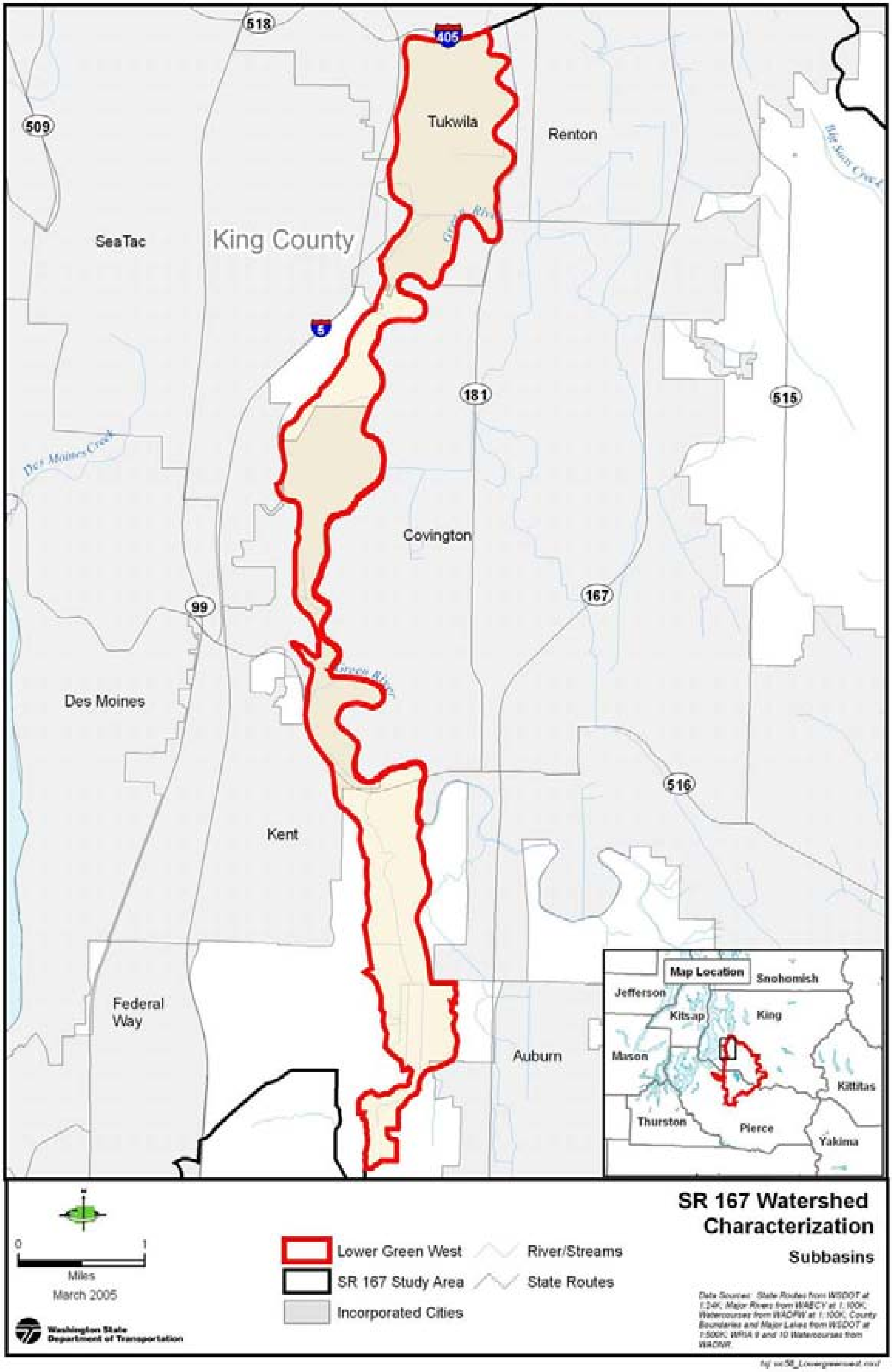


Figure 12. Lower Green West Subbasin.

Hydrogeology and groundwater recharge

The lower Green flows through extensive alluvial deposits on the valley floor. Tributaries arise from the Federal Way uplands, and cut steeply through ravines before emerging as sloughs on the valley floor. Seepage zones line the eastern and western edges of the valley where bluffs have exposed advance outwash and pre-Fraser deposits.

An extensive alluvial aquifer system occupies the lower Green valley. Alluvial deposits in the valley range from 40 to 300 feet thick. The alluvium is underlain by recessional delta sands and gravels that were deposited at the end of the last ice age (Pacific Groundwater Group, 1999). Clays and mudflow deposits separate the recessional delta deposits from the alluvial aquifer.

Most of the recharge for the alluvial and recessional delta aquifer comes from seepage from outwash aquifers on the Covington and Federal Way Uplands. Recessional outwash terraces line the valley margins and provide high rates of recharge, but occupy only four percent of the total subbasin area. Thirty-one percent of these outwash deposits are now covered by impervious surfaces. King County has designated the entire Lower Green valley floor as a High Critical Aquifer Recharge Area.

Runoff and streamflow

Dams, diversions, and levees have drastically altered the hydrology of the Lower Green River. Howard Hanson Dam limits flows at Auburn to less than 12,000 cfs (equivalent to the pre-dam 2-year flood). Levees are virtually continuous along both banks downstream of River Mile 25 (Kerwin and Nelson, 2000). These alterations have effectively disconnected the Green River from its historical floodplain. Flooding on the valley floor is now caused primarily by high groundwater levels in topographic depressions and wetlands (Federal Emergency Management Agency, 1989).

The dam also augments summer flows to compensate for diversions by the City of Tacoma. However, the diversions still reduce the average seven-day low flow at Auburn by seven percent. Flows at Auburn have failed to meet Ecology's minimum instream flow requirements in 21 of the last 30 years (Kerwin and Nelson, 2000).

Historically the glacier-fed White River was an important source of cold water to the lower Green, and provided 75 percent of the river's coarse sediment. In the early 1900's a log jam diverted the entire White River into the Puyallup through an overflow channel formerly called the Stuck River. A diversion structure was constructed in 1911 to keep the White River in this configuration. The loss of flow from the glacier-fed White reduced summer flows in the Green by about 50 percent (Kerwin and Nelson, 2000). Groundwater still flows from the White to the Green, contributing about 56 cfs to the lower Green in the late summer (Pacific Groundwater Group, 1999).

Most of the subbasin is heavily developed, with a TIA of 41 percent. This has increased peak flows, erosion, and delivery of fine sediment in tributary streams. These hydrologic changes are substantial within tributaries, but have only minor impacts to the mainstem Green because of the overwhelming flow regime changes associated with diversions, channel modifications, and dam operations (Kerwin and Nelson, 2000).

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Lower Green West Subbasin totaled approximately 1,334 acres and represented 50 percent of the subbasin. Of this pre-development total, we estimate that all were wetlands. No natural deepwater lakes were noted. We estimate that approximately 713 acres, or 27 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-three percent of the original 1,334 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 77 acres of wetlands in the Lower Green West Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 11 percent of all existing or potential wetlands (713 acres) and six percent of all historic wetlands (1,334 acres). Eighty-six percent (614 acres) of the 713 acres of current or potential wetlands have evidence of hydrologic alteration, while 89 percent (635 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 635 acres (89 percent) of the 713 current or potential wetland acres in the Lower Green West Subbasin are considered altered.

Of the 713 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower Green West Subbasin include 595 acres of depressional wetlands (83 percent) and 118 acres of riverine wetlands (17 percent). Anadromous fish are estimated to have access to 87 percent (622 acres) of the 713 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on much of the 67-meter wide riparian corridors in the Lower Green River West basin, but there are still some forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Only 28 percent of the riparian zone remains forested, or 212 acres of 747 total acres, and road crossings have disconnected many of these areas. Of the non-forested riparian corridor, however, 16 areas comprising 157 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The Green River valley has undergone dramatic changes in floodplain conditions since the 1800’s, most notably construction of the Howard Hanson Dam in 1962. This project controls flood flows through the rest of the system limiting peak flow to 12,000 cfs. This is roughly equivalent to the two-year unregulated flow. In addition extensive levees have further de-coupled most of the floodplain from the Green River. As a result, much of it has been removed from floodplain jurisdictions for development.

Of 3,779 acres of original floodplain in the Lower Green river subbasins only 1,281 acres remain. The Lower Green West subbasin has been particularly affected having lost 91 percent of its historic floodplain.

Water quality

This highly urbanized subbasin lies adjacent to and west of the Black River subbasin and exhibits many of the same pollutant loss characteristics. There is little variation in land cover or soil types between the Lower Green River West and Black River subbasins, so runoff and pollutant loading characteristics are very similar. No state highways contribute runoff or pollutants loads to the Lower Green River West subbasin.

Fish resources

Chinook, coho, steelhead, pink, sockeye, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. Chinook are found primarily in the mainstem Green and larger tributaries (Black River and Mill Creek, both reported below). Coho, cutthroat and steelhead will utilize the same tributaries, though will generally penetrate farther upstream; in addition, coho and cutthroat utilize numerous smaller, unnamed tributaries. Pink salmon and sockeye are found in the mainstem Green.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Lower Green River and its tributaries in the Lower Green West Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Lower Green West Subbasin consists of DAUs considered to be in an "at risk" or a "not properly functioning" condition for the delivery of water. The two southernmost DAUs in this long, linear subbasin are considered "at risk," while the two northern DAUs are considered "not properly functioning" (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Lower Green River and its tributaries in the Lower Green West Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Lower Green West Subbasin is in an "at risk" condition for the delivery of sediment (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Lower Green River and its tributaries in the Lower Green West Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Lower Green West Subbasin is primarily in a “not properly functioning” condition for the delivery and routing of large wood. The lone exception is the northernmost DAU considered to be in an “at risk” condition (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Lower Green River and its tributaries in the Lower Green West Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Lower Green West Subbasin is predominantly in a “not properly functioning” condition for aquatic integrity. The lone exception is the southernmost DAU considered to be in an “at risk” condition (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 20 percent (530 total forested acres) of the relatively small and narrow Lower Green River West Subbasin. Most of the remaining forest lies along the slopes of the west valley wall (Figure 58, “Upland Forest Cover”). Due to the widely dispersed forest cover in the Lower Green River West Subbasin, it is considered “not properly functioning” for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Middle Green River Subbasin?

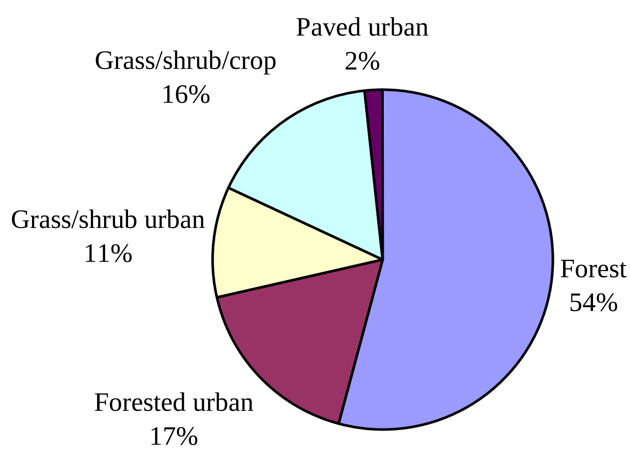
The Middle Green Subbasin includes areas that drain directly to the Green River upstream of Soos Creek, as well as small side canyon tributaries such as Crisp Creek, O'Grady Creek, and Burns Creek (see Figure 14, Middle Green River Subbasin). These areas drain a total of 20,971 acres.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Agriculture and rural residential development are the primary land uses in this subbasin (see Figure 13, Current Land Use in the Middle Green River Subbasin). Substantial forested areas (over 50 percent of the subbasin) remain along streams and in headwater areas of Crisp Creek and other tributaries that are managed for commercial timber production.



Land cover data from 1998 Landsat images.

Figure 13. Current Land Use in the Middle Green River Subbasin.

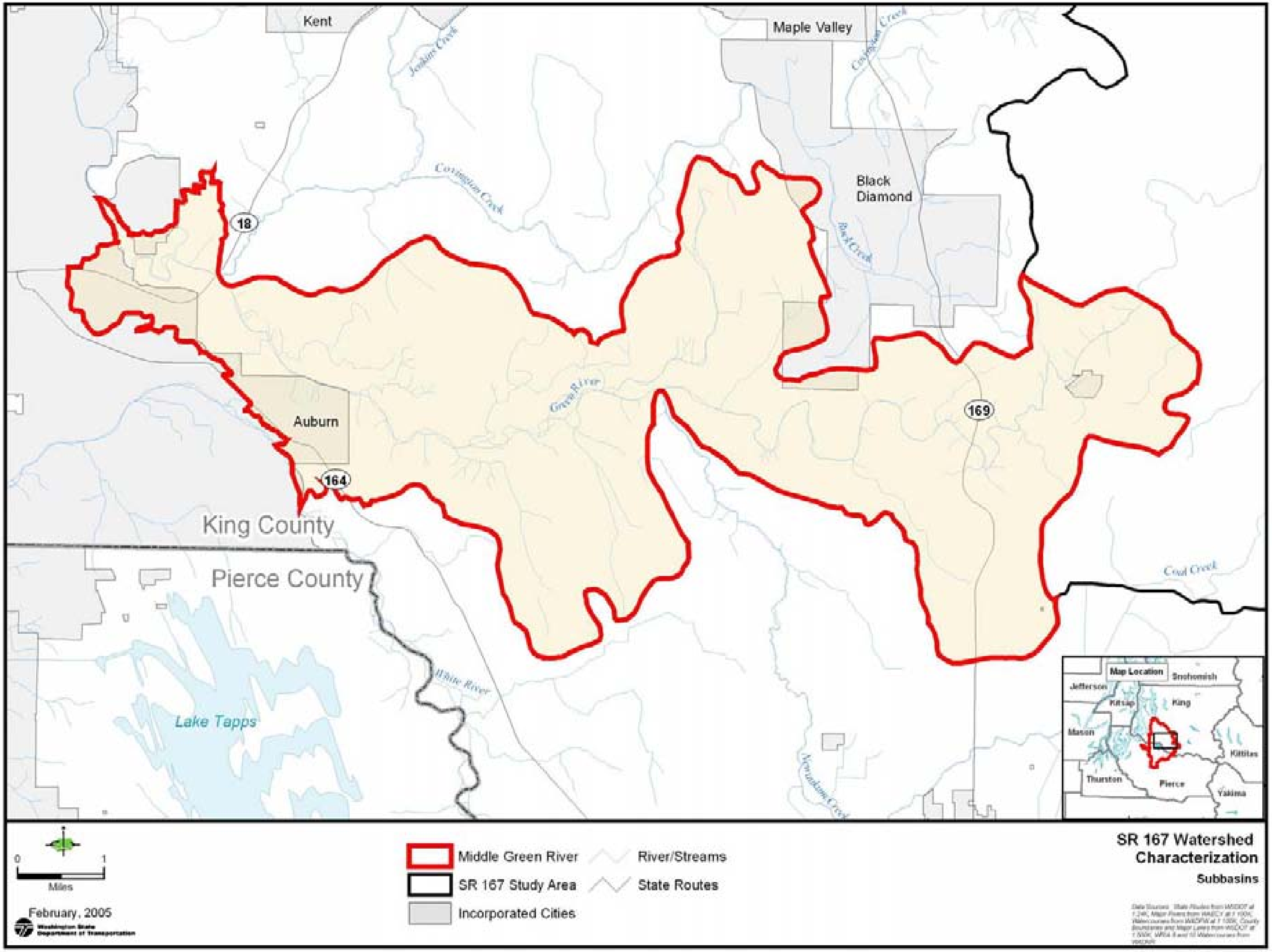


Figure 14. Middle Green River Subbasin.

Future conditions

Future land use in the Middle Green River Subbasin is predicted to reflect a sharp increase in urban character, with residential and commercial development increasing the TIA from 19 percent to 30 percent, a 59 percent increase.

Hydrogeology and groundwater recharge

The valley floor of the Middle Green is covered by alluvium deposited after the end of the last ice age. Below Newaukum Creek the valley walls are lined by seepage zones in advance outwash and pre-Fraser deposits exposed by steep bluffs. However, Pacific Groundwater Group (1999) found relatively low seepage rates from these edges of the Covington and Enumclaw uplands (when compared to the western edge of the Covington upland).

The Middle Green and White River form an alluvial fan of coarse sediment as they enter the Auburn-Kent valley. A combined alluvial and recessional delta aquifer occupies this fan, and is the primary water supply for the City of Auburn (Pacific Groundwater Group, 1999). This aquifer is recharged by infiltrated rainfall and seepage from the Covington and Enumclaw uplands. King County has designated most of the valley floor as a High Critical Aquifer Recharge Area because of the vulnerability of the shallow alluvial aquifer to contamination.

Extensive recessional outwash deposits line the valley margins upstream of Newaukum Creek. These outwash terraces are important sources of groundwater recharge, and cover 28 percent of the subbasin. Impervious surfaces cover 20 percent of these areas.

Tributaries such as Crisp Creek, O'Grady Creek, and Burns Creek drain glacial till and Osceola mudflow deposits on the Enumclaw Plateau and Covington upland. These tributaries cut steeply through ravines before emerging onto alluvial fans on the valley floor.

Runoff and streamflow

The hydrology of the Middle Green River is strongly influenced by upstream dams and diversions. In 1913 the City of Tacoma began diverting up to 12 percent of the average annual flow at Palmer (Kerwin and Nelson, 2000). Howard Hanson Dam was constructed in 1961 for flood control and storage, and limits flows at Auburn to less than 12,000 cfs (equivalent to the pre-dam 2-year flood). The dam stores runoff from the upper 200 square miles of the Green River basin.

The dam has combined with an extensive levee system to effectively eliminate flooding and channel migration in most of the historical Green River floodplain. The dam has also caused substantial changes in the river's sediment transport regime. The upper basin once supplied over 90 percent of the alluvial gravel deposited in the middle and lower reaches of the Green River (Kerwin and Nelson, 2000). The dam traps nearly all of this coarse sediment, while allowing most of the suspended load to be carried downstream. The river has responded to this deficit of coarse sediment by eroding and armoring its bed, particularly in reaches immediately downstream of the Green River Gorge. Most of the coarse sediment in the Middle Green is now derived from landslides and tributary alluvial fans.

The dam also augments flows in the summer to partially compensate for the Tacoma diversion. However, the diversion still reduces the average 7-day low flow at Auburn by seven percent. Flows at Auburn have failed to meet Ecology's minimum instream flow requirements in 21 of the last 30 years (Kerwin and Nelson, 2000).

Land clearing and development have increased the TIA in the subbasin to 19 percent, and have increased peak winter flows, reduced recharge of shallow aquifers, and decreased dry season flows. These hydrologic changes are substantial within tributaries, but have only minor impacts to the mainstem Green because of the overwhelming flow regime changes associated with diversions, channel modifications, and dam operations (Kerwin and Nelson, 2000).

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Middle Green River Subbasin totaled approximately 3,917 acres and represented 19 percent of the subbasin. Of this pre-development total, we estimate that all were wetlands. No natural deepwater lakes were noted. We estimate that approximately 2,290 acres, or 11 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-nine percent of the original 3,917 predevelopment wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 1,068 acres of wetlands in the Middle Green River Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 47 percent of all existing or potential wetlands (2,290 acres) and 27 percent of all historic wetlands (3,917 acres). Forty-six percent (1048 acres) of the 2,290 acres of current or potential wetlands have evidence of hydrologic alteration, while 50 percent (1,155 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1,222 acres (53 percent) of the 2,290 current or potential wetland acres in the Middle Green River Subbasin are considered altered.

Of the 2,290 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Middle Green River Subbasin include 1,337 acres of depressional wetlands (58 percent) and 953 acres of riverine wetlands (42 percent). Anadromous fish are estimated to have access to 38 percent (870 acres) of the 2,290 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the Middle Green River basin, but there are still significant forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Of the 3,569 total acres, 2,633 acres or 74 percent of the riparian zone remain forested, though road crossings have disconnected some of these areas. Of the non-forested riparian corridor, 42 areas comprising 335 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The Green River valley has undergone dramatic changes in floodplain conditions since the 1800's, most notably construction of the Howard Hanson Dam in 1962. This project controls flood flows through the rest of the system limiting peak flow to 12,000 cfs. This is roughly equivalent to the two-year unregulated flow. In addition extensive levees have further de-coupled most of the floodplain from the Green River. As a result, much of it has been removed from floodplain jurisdictions for development.

The Middle Green subbasin once contained 3,217 acres of floodplain. This has been reduced to 1,714 acres, a loss of 47 percent. Despite extensive flow regulation and channel modification, flooding still does occur form interior drainage runoff that outlets to the Green River from Mill Creek, the Black River, Mullen slough and various outlets in Auburn and south and west of State Routes 516 and 167.

Water quality

Land cover in the Middle Green River Subbasin transitions from densely forested foothills in the easternmost DAUs of the project area to urban (downtown Auburn) in the west. Significant portions of the southern half of the subbasin are also covered by Osceola mudflow deposits, which have very high clay content and correspondingly high runoff rates. Water quality conditions in the Green River consistently improve as one moves upstream due to the lower level of urbanization and the larger percentage of forest lands and outwash soils in the easternmost DAUs of the subbasin.

Fish resources

Chinook, coho, steelhead, pink, sockeye, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. All species utilize the mainstem Green for spawning and/or rearing.

Chinook are found primarily in the mainstem Green and larger tributaries (Newaukum Creek – reported below, Burns Creek, Crisp Creek, Cristy Creek, Icy Creek, numerous unnamed tributaries). Coho, cutthroat and steelhead will utilize the same tributaries, though will generally penetrate farther upstream. Pink salmon and sockeye are found in the mainstem and in the lowermost reach of Soos Creek (reported below).

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Green River and its tributaries in the Middle Green River Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Middle Green River Subbasin is nearly all in an "at risk" condition for the delivery of water. The one exception is the westernmost DAU in the subbasin, that is considered to be in a “not properly functioning” condition (Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Green River and its tributaries in the Middle Green River Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Middle Green River Subbasin is in an “at risk” condition for the delivery of sediment (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Green River and its tributaries in the Middle Green River Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Middle Green River Subbasin is primarily in an “at risk” condition for the delivery and routing of large wood. Exceptions include one DAU on the western edge and two DAUs on the eastern edge of the subbasin that are considered to be “properly functioning” and four randomly distributed DAUs that are “not properly functioning” (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Green River and its tributaries in the Middle Green River Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Middle Green River Subbasin is in an “at risk” condition for aquatic integrity. An exception is the westernmost DAU in this subbasin considered to be in a “not properly functioning” condition (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 54 percent (11,284 total forested acres) of the Middle Green River Subbasin. Most of the remaining forest lies along the wide riparian corridor of the Green River, forming a cohesive patch from the study area boundary to the valley floor, including a connection to the White River’s forest (Figure 58, “Upland Forest Cover”). Uphill of the Green River’s riparian corridor the forest patches are widely dispersed, the Middle Green River Subbasin is considered “at risk” for upland forest cover, and the subbasin has a median probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Mill Creek Subbasin?

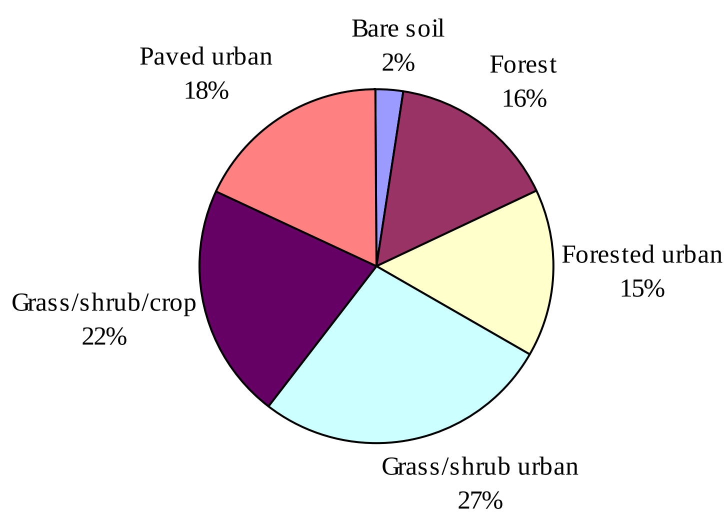
Mill Creek drains 9,673 acres on the Federal Way uplands and Auburn-Kent valley floor (see Figure 16, Mill Creek Subbasin).

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Sixty percent of the Mill Creek Subbasin is covered by urban land uses (see Figure 15, Current Land Use in the Mill Creek Subbasin). Residential uses are concentrated in the western portion of the basin, on the Federal Way uplands above Peasley Canyon. Commercial and industrial development has been increasing rapidly on the valley floor, and is usually built on fill that has been placed within floodplains and wetlands along the lower reaches of Mill Creek.



Land cover data from 1998 Landsat images.

Figure 15. Current Land Use in the Mill Creek Subbasin.

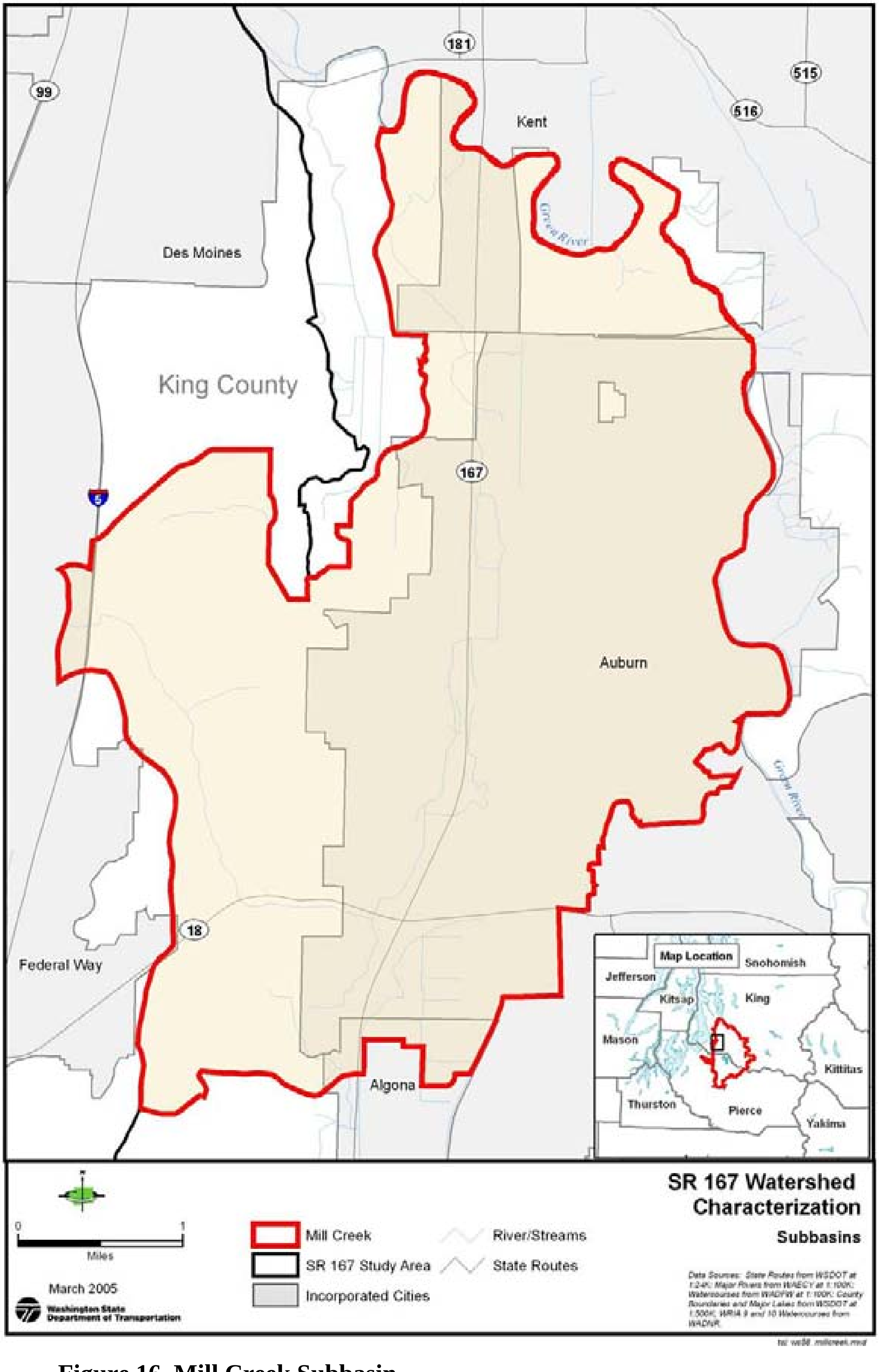


Figure 16. Mill Creek Subbasin.

Future conditions

Future land use in the Mill Creek Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 46 percent to 52 percent.

Hydrogeology and groundwater recharge

The headwaters of Mill Creek begin on the eastern edge of the Federal Way uplands. Tributary streams cut canyons through the till deposits on the upland bluffs, and intercept seepage zones in the bands of advance outwash and pre-Fraser deposits that are exposed at the base of the bluffs. These seepage zones also recharge alluvial aquifers and wetlands on the valley floor, and feed springs used for water supply by the City of Auburn.

Most of the lower basin is within the Green River alluvial aquifer system. This aquifer is recharged by infiltration through the alluvium and seepage from glacial outwash aquifers on the Federal Way and Covington uplands. King County has designated most of the valley floor as a High Critical Aquifer Recharge Area, because of the vulnerability of the shallow alluvial aquifer to contamination.

Runoff and streamflow

Mill Creek arises from four lakes (Dolloff, Fenwick, Geneva, and Star), wetlands, and seeps on the Federal Way uplands, in rolling hills that lie 300-400 feet above the valley floor. Most of the runoff from these till-covered headwater areas was historically produced as shallow subsurface flow. The creek drops through Peasley Canyon before flowing north onto the valley floor. Fine-grained alluvial soils on the valley floor saturate quickly, but runoff would historically have been captured in the extensive wetland complex that once dominated the lower basin.

Most of the basin is now heavily developed, with 46 percent TIA. This has increased peak streamflows and erosion rates in the upper ravines, and sedimentation in the lower reaches. Below Peasley Canyon Mill Creek parallels SR-167 and has been extensively modified. The creek crosses SR-167 several times, and has been relocated to accommodate industrial and commercial development. A levee system disconnects the Green River from much of its historical floodplain within the Mill Creek subbasin. However, floodwater still backwaters from the Green into the lower reaches of Mill Creek.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Mill Creek Subbasin totaled approximately 4,881 acres and represented 50 percent of the subbasin. Of this pre-development total, we estimate that 4,849 acres (50 percent of subbasin) were wetlands and 32 acres (less than one percent of subbasin) were natural deepwater lakes. We estimate that approximately 1,566 acres, or 16 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Thirty-two percent of the original 4,849 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 223 acres of wetlands in the Mill Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 14 percent of all existing or potential wetlands (1,566 acres) and five percent of all historic wetlands (4,849 acres). Eighty-five percent (1,337 acres) of the 1566 acres of current or potential wetlands have evidence of hydrologic alteration, while 84 percent (1,312 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1,343 acres (86 percent) of the 1,566 current or potential wetland acres in the Mill Creek Subbasin are considered altered.

Of the 1,566 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Mill Creek Subbasin include 1,420 acres of depressional wetlands (91 percent) and 65 acres of riverine wetlands (four percent). Anadromous fish are estimated to have access to 37 percent (588 acres) of the 1,597 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on most of the 67-meter wide riparian corridors in the Mill Creek basin, but there are still some forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Only 23 percent of the riparian zone remains forested, or 295 acres of 1,273 total acres, and road crossings have disconnected many of these areas. Of the non-forested riparian corridor, however, 19 areas comprising 172 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

Flooding occurs almost annually in the Mill Creek Subbasin, principally in parts of the valley floor, causing road damage, crop and livestock problems, erosion hazards and flood damage to businesses, homes, and roads. Agricultural and urban development are causing more water to run off the landscape and collect in low areas than ever before. Flooding in the basin has two causes. First, water confined by levees to a narrow channel in the Green River backs up into the mouths of Mill Creek and Mullen Slough, which lack flood gates, from the Green River. The Green River backwater most commonly affects Mill Creek and Mullen Slough downstream of South 277th Street to their confluence with the Green River. This problem has been severely aggravated by the filling of floodplain/flood retention areas. Of the 6,071 acres of original floodplain in the Mill Creek Subbasin only 1,426 remain, a loss of 77 percent of the original floodplain area.

The second main cause of flooding in the Mill Creek valley floor is runoff generated within the basin. The combination of local runoff generated by basin tributaries and a seasonally high water table often causes water to overtop stream banks in the valley floor upstream of the Green River backwater, and aggravates flooding in the backwater areas. Poorly maintained ditches and culverts and improperly sized culverts also are contributing to local flooding problems.

Hydrologic and hydraulic modeling studies of the Mill Creek Subbasin show that existing flooding and runoff problems in Mill Creek will continue to worsen, even with required stormwater runoff control measures in place, as urban development expands in the basin. These problems include increased peak annual flows, more frequent high flows, a higher than natural volume of winter flows, and lower than natural dry season flows (King County 1987; Northwest Hydraulic Consultants 1993). The possibility of providing effective regional stormwater detention in upland areas of the basin has been examined and found to be unfeasible (Auburn, City of, et al, 2000).

Water quality

The northernmost half of the Mill Creek subbasin abuts the southern end of Black River subbasin, and shares many of its land cover and soil characteristics. It is highly urbanized and heavily industrialized, with shallow water tables. High runoff rates predominate. The southwestern portion of the Mill Creek subbasin transitions to agricultural land uses with extensive areas of low grade wetlands, but little urbanization. Mill Creek itself is a very low gradient, mechanically channelized backwater area to the Green River that generally runs northward and parallel to SR-167. SR-167 and SR-18 both contribute runoff to the Mill Creek subbasin.

Fish resources

Chinook, coho, steelhead, and cutthroat spend one or more parts of their life cycle in this subbasin. Chinook are found only in Mill Creek; coho, steelhead, and cutthroat will generally penetrate farther upstream; coho and cutthroat also utilize several smaller, unnamed tributaries.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Mill Creek and its tributaries in the Mill Creek Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the entire Mill Creek Subbasin is in a “not properly functioning” condition for the delivery of water (Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Mill Creek and its tributaries in the Mill Creek Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Mill Creek Subbasin is in an “at risk” condition for the delivery of sediment (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Mill Creek and its tributaries in the Mill Creek Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Mill Creek Subbasin is primarily in a "not properly functioning" condition for the delivery and routing of large wood. Exceptions include two DAUs that are conditioned to be in "at risk" (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the Mill Creek and its tributaries in the Mill Creek Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Mill Creek Subbasin is predominantly in a "not properly functioning" condition for aquatic integrity. The lone exception is the southwesternmost DAU in the subbasin considered to be in an "at risk" condition (Figure 56, "Condition Map for Aquatic Integrity," and Figure 57, "Overall Condition map for Aquatic Integrity").

Upland forest cover

Forest covers only 16 percent (1,498 total forested acres) of the Mill Creek Subbasin, concentrated in small, scattered patches along the western valley wall (Figure 58, "Upland Forest Cover"). Most of the remaining forest lies on steep slopes, and the subbasin's primary land cover is composed of increasingly dense urban, agricultural and commercial areas. The Mill Creek Subbasin is considered "not properly functioning" for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, "Final Condition Map for Forest Density Areas").

What conditions did we find in the Newaukum Creek Subbasin?

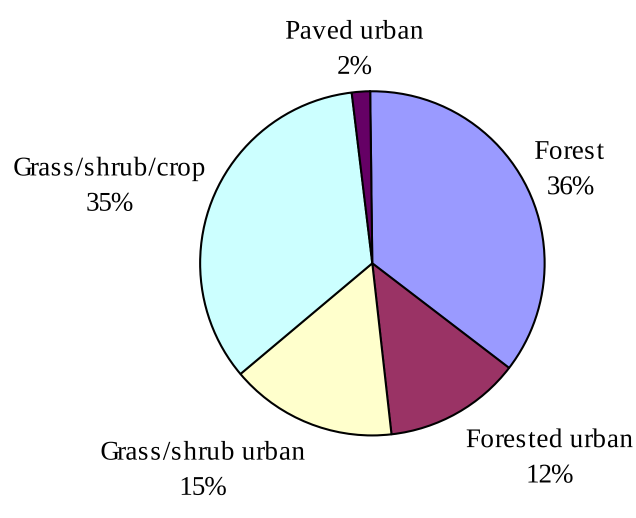
Newaukum Creek drains 17,821 acres on the Enumclaw Plateau (see Figure 18, Newaukum Creek Subbasin).

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

The Newaukum Creek Subbasin has the highest concentration of agricultural land in the Green River watershed, with 35 percent grass/shrub/crop land cover (see Figure 17, Current Land Use in the Newaukum Creek Subbasin). Much of this land is used for pasture and hay production. Thirty-six percent of the subbasin is forested, including most of the ravine along the lower reaches of the creek and commercial timber areas in the headwaters. Urban land uses are concentrated near the City of Enumclaw, and cover 29 percent of the subbasin.



Land cover data from 1998 Landsat images.

Figure 17. Current Land Use in the Newaukum Creek Subbasin.

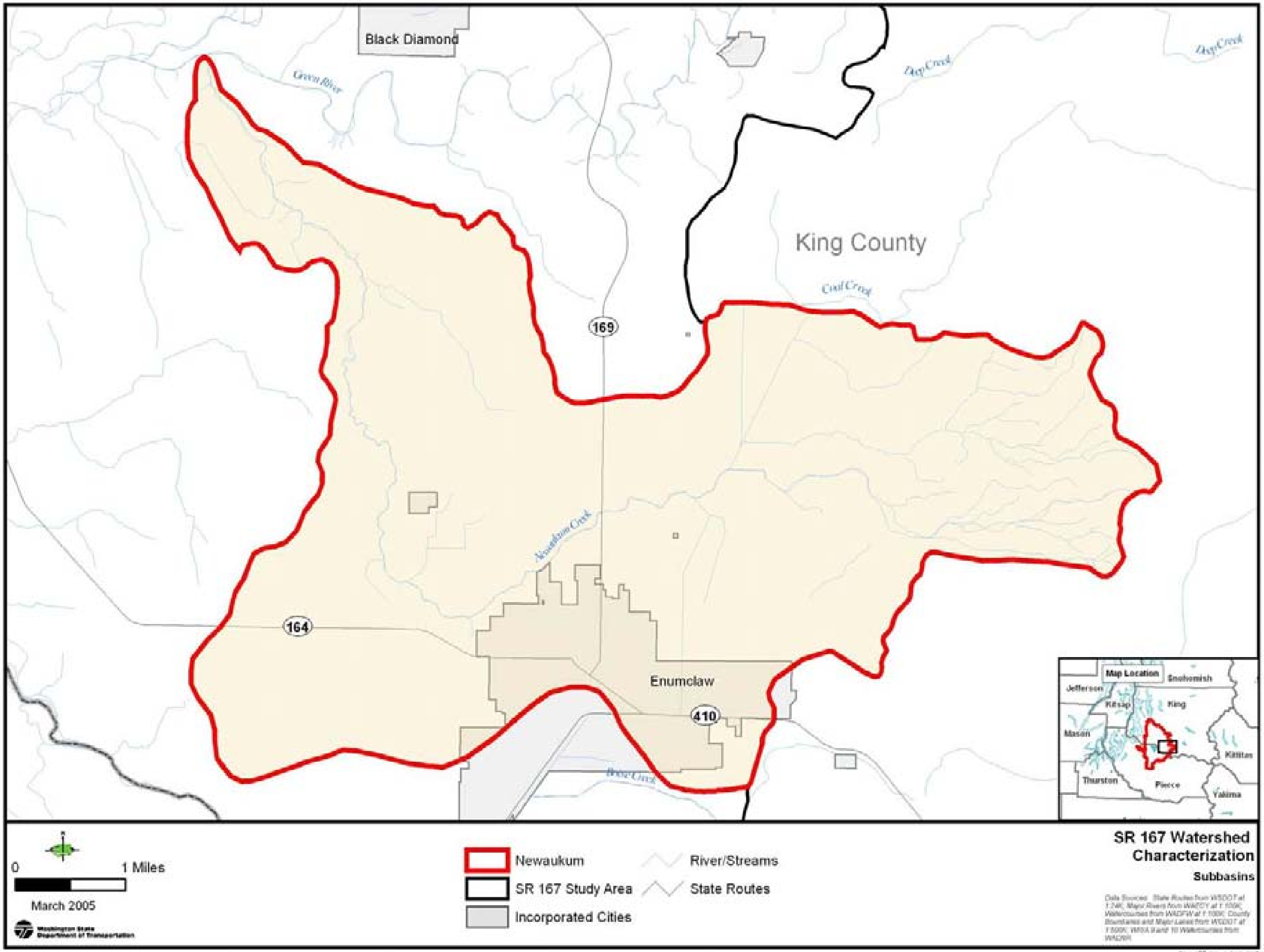


Figure 18. Newaukum Creek Subbasin.

Future conditions

Future land use in the Newaukum Creek Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 21 percent to 25 percent.

Hydrogeology and groundwater recharge

Most of the Newaukum Creek basin was covered by the Osceola mudflow during an eruption of Mount Rainier 5000 years ago. Minor inclusions of glacial till remain exposed within the mudflow deposits. Recessional outwash deposits cover 23 percent of the basin, and are concentrated in the headwaters and along the Green River valley bluffs on the northern margins of the basin. 21 percent of these important groundwater recharge areas are now covered by impervious surfaces.

Newaukum Creek begins as a low-gradient channel flowing across broad mudflow plains. As it drops down into the Green River valley the creek carves a ravine into the glacial deposits and intercepts groundwater in advance outwash and pre-Fraser deposits. The creek forms an alluvial fan at the mouth of the ravine. Hydrologic changes in the basin have increased the rate of sediment deposition in the alluvial fan, which is periodically dredged to maintain fish passage from the Green River.

Runoff and streamflow

The headwaters of Newaukum Creek arise from diffuse springs, snowmelt, and groundwater runoff on Boise Ridge in the foothills of the Cascades. Mudflow deposits on the Enumclaw Plateau are relatively impervious, and produce runoff rapidly when compared to the glacial deposits that cover other Green River Subbasins. King County Department of Natural Resources (1997) found that streamflows from a January 1997 storm peaked more than two days before streamflows peaked in outwash-dominated basins like Soos Creek.

Agriculture is still the dominant land use in the basin, but urban development has increased the TIA to 21 percent. Conversion of forest to agriculture, elimination of historic wetlands, and water withdrawals have increased stormwater runoff and decreased dry season low flows. Numerous wetlands once occupied the relatively flat and impermeable mudflow deposits, and played a key role in delaying stormwater runoff. Most of these wetlands have been ditched and drained for agriculture, resulting in considerable loss of water storage in the basin.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Newaukum Creek Subbasin totaled approximately 6,933 acres and represented 39 percent of the subbasin. Of this pre-development total, we estimate that all 6,933 acres were wetlands. No natural deepwater lakes were noted in this subbasin. We estimate that approximately 3,794 acres, or 21 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-five percent of the original 6,933 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 135 acres of wetlands in the Newaukum Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent four percent of all existing or potential wetlands (3,794 acres) and two percent of all historic wetlands (6,933 acres). Ninety-five percent (3,606 acres) of the 3,794 acres of current or potential wetlands have evidence of hydrologic alteration, while 95 percent (3,604 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 3,658 acres (96 percent) of the 3,794 current or potential wetland acres in the Newaukum Creek Subbasin are considered altered.

Of the 3,794 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Newaukum Creek Subbasin include 3,579 acres of depressional wetlands (94 percent) and 215 acres of riverine wetlands (six percent). Anadromous fish are estimated to have access to 46 percent (1,742 acres) of the 3,794 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the Newaukum Creek basin, but there are still significant forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Of the 2,617 total acres, 58 percent or 1,529 acres of the riparian zone remains forested, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, 34 areas comprising 287 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of considerable size were evaluated in the Newaukum Creek Subbasin for this study. Potential restoration sites in floodplain areas for this sub-basin were evaluated in terms of potential aquatic habitat, wetland, and/or riparian functions (see sections on wetlands and riparian).

Water quality

Runoff characteristics for the Newaukum Creek Subbasin are mostly defined by the large expanses of very low permeability mudflow deposits, large tracts of agricultural land, and ongoing conversion of farmland to residential developments. As a result, the Newaukum Creek subbasin exhibits elevated runoff of nutrients, sediments, and bacteria. The only properly functioning DAUs in the subbasin lie in the easternmost sections, which are mostly forested.

Fish resources

Chinook, coho, steelhead, pink, sockeye, and cutthroat spend one or more parts of their life cycle in this subbasin.

Chinook are found in Newaukum Creek, Spring Creek, and the N. Fork Newaukum. Coho, steelhead, and cutthroat utilize these streams as well, though will generally penetrate farther upstream; coho and cutthroat also utilize several smaller tributaries (Watercress Creek, Stonequarry Creek, unnamed tributary at RM 2.8). Pink salmon and sockeye are found only in Newaukum Creek.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Newaukum Creek and its tributaries in the Newaukum Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that nearly all of the DAUs in the Newaukum Subbasin are in an "at risk" condition for the delivery of water. The one exception is the DAU associated with the town of Enumclaw that is considered to be in a "not properly functioning" condition (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Newaukum Creek and its tributaries in the Newaukum Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the Newaukum Subbasin is in an "at risk" condition for the delivery of sediment. The lone exception is a single forested DAU on the eastern edge of the subbasin that is considered to be in a "not properly functioning" condition (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Newaukum Creek and its tributaries in the Newaukum Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Newaukum Subbasin has a mix of condition ranks for the delivery and routing of large wood. Two DAUs are considered to be "properly functioning," three DAUs are considered to be "at risk," and six DAUs are considered to be in a "not properly functioning" (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the Newaukum Creek and its tributaries in the Newaukum Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Newaukum Subbasin is primarily in an "at risk" condition for aquatic integrity. Exceptions include two DAUs considered to be "not properly functioning" and one considered to be "properly functioning" (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 36 percent (6,349 total forested acres) of the Newaukum Creek Subbasin. Most of the remaining forest cover is scattered around the plateau, fragmented by agricultural land use, but there is one larger patch along the northern part of the subbasin that connects to the Middle Green River’s network of forest cover, and the upper reaches of Newaukum Creek on the east side of the subbasin contain a large forested complex (Figure 58, “Upland Forest Cover”). The Newaukum Creek Subbasin is considered “at risk” for upland forest cover with a median probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Soos Creek Subbasin?

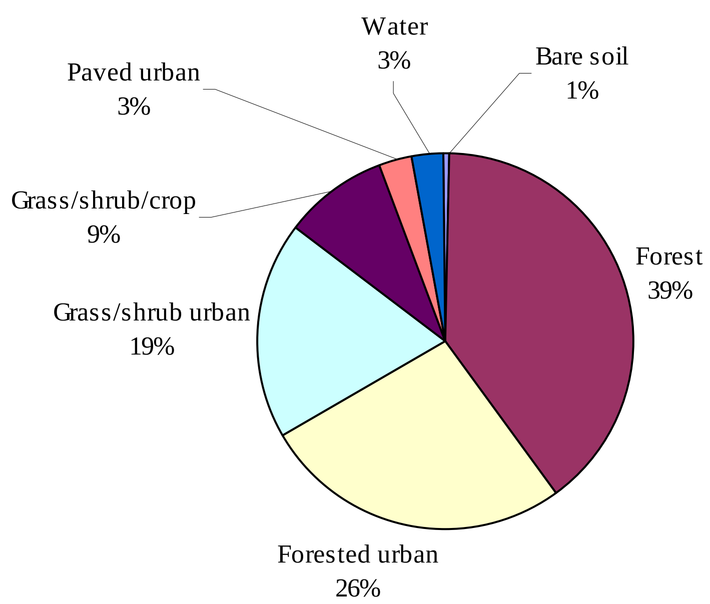
The Soos Creek Subbasin covers 20,405 acres on the Covington Uplands (see Figure 20, Soos Creek Subbasin). The Soos Creek is fed by Jenkins Creek, Covington Creek, and Little Soos (Soosette) Creek, and has a total drainage area of 44,875 acres. In this study, Jenkins Creek and Covington Creek are treated as independent subbasins.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

The Soos Creek Subbasin is one of the most rapidly developing areas in the King County (see Figure 19, Current Land Use in the Soos Creek Subbasin). The northern and western areas contain the high densities of residential and commercial development, especially near Kent and Renton. Urban land near the city of Covington cover the lower section of the Little Soos watershed. Other areas are still rural, but are rapidly converting to more intense uses. Forested land is concentrated in the headwaters and in wetland and riparian areas.



Land cover data from 1998 Landsat images.

Figure 19. Current Land Use in the Soos Creek Subbasin.

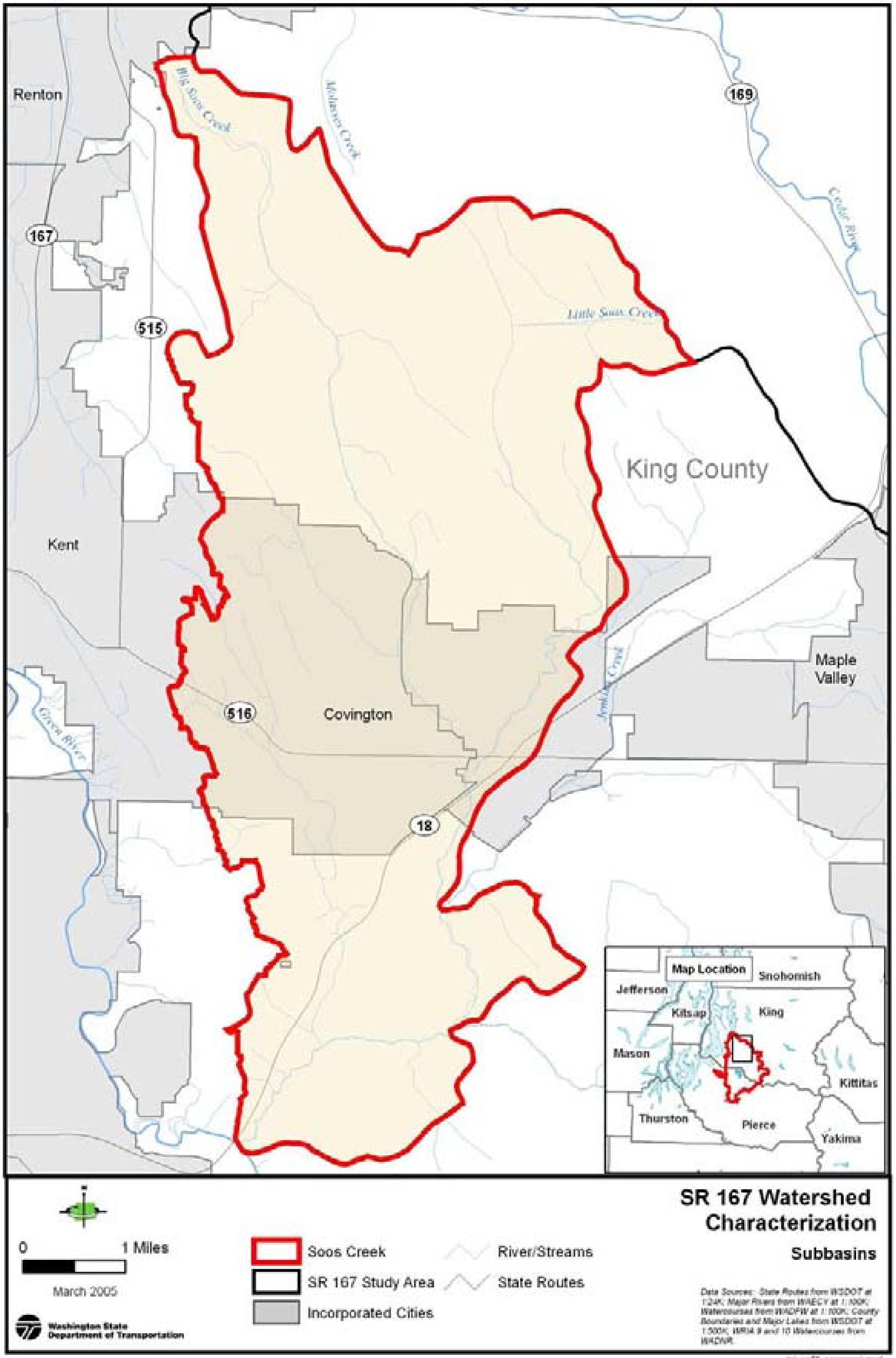


Figure 20. Soos Creek Subbasin.

Future conditions

Future land use in the Soos Creek Subbasin is predicted to reflect a fairly strong increase in residential and commercial development, increasing the TIA from 33 percent to 42 percent, an increase of 26 percent.

Hydrogeology and groundwater recharge

Soos Creek drains glacial deposits on the Covington Uplands. Recessional outwash deposits cover 18 percent of the basin, and are concentrated on the valley floor. Groundwater is close to the surface in many of these areas, and provides an important source of water for streams and valley bottom wetlands. Impervious surfaces now cover 33 percent of the outwash deposits, reducing groundwater recharge and proportionally increasing surface runoff.

Soos Creek intercepts groundwater in advance outwash and pre-Fraser deposits exposed by erosion below Jenkins Creek. The creek discharges onto an alluvial fan before entering the Green River. Advance outwash and pre-Fraser deposits make up the most important aquifers in the subbasin, and are tapped by Kent, Renton, Bonney Lake, and various community water systems. King County designates High Critical Aquifer Recharge Areas in recessional outwash deposits in the Soos Creek valley, recognizing the vulnerability of shallow groundwater in these areas to contamination.

Runoff and streamflow

Streamflows in the Soos Creek basin were historically fed by shallow subsurface and groundwater flow through coarse recessional outwash deposits. Numerous lakes and valley bottom wetlands delayed runoff and provided flood storage. Lakes cover a total surface area of 1,370 acres in the Soos Creek watershed (Kerwin and Nelson, 2000). Soos Creek is dominated by groundwater flow, and is therefore highly sensitive to the hydrologic changes associated with urban development.

The subbasin is rapidly developing, and now has a TIA of 32 percent. Much of this development is happening on coarse soils that under natural conditions would have had high infiltration and low runoff rates. The Soos Creek Basin Plan estimates that peak flows will increase by a factor of 1.8 under build-out conditions (Kerwin and Nelson, 2000). Development has also decreased streamflows during dry periods; both the mean annual flow and the average seven-day low flow decreased significantly in Soos Creek between 1967 and 1992 (Kerwin and Nelson, 2000).

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Soos Creek Subbasin totaled approximately 2,407 acres and represented 12 percent of the subbasin. Of this pre-development total, we estimate that 2,215 acres (11 percent of subbasin) were wetlands and 192 acres (one percent of subbasin) were natural deepwater lakes. We estimate that approximately 1,822 acres, or nine percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential.

Eighty-two percent of the original 2,215 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 476 acres of wetlands in the Soos Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 26 percent of all existing or potential wetlands (1,822 acres) and 21 percent of all historic wetlands (2,215 acres). Sixty-three percent (1,153 acres) of the 1,822 acres of current or potential wetlands have evidence of hydrologic alteration, while 74 percent (1,341 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1,346 acres (74 percent) of the 1,822 current or potential wetland acres in the Soos Creek Subbasin are considered altered.

Of the 1,822 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Soos Creek Subbasin include 1,611 acres of depressional wetlands (88 percent) and 206 acres of riverine wetlands (11 percent). Anadromous fish are estimated to have access to 48 percent (962 acres) of the 2,014 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the Soos Creek basin, but there are still significant forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Forty-seven percent of the riparian zone remains forested, or 1,196 acres of 2,566 total acres, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, 28 areas comprising 152 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of considerable size were evaluated in the Soos Creek Subbasin for this study. Potential restoration sites in floodplain areas for this subbasin were evaluated in terms of potential aquatic habitat, wetland, and/or riparian functions (see sections on wetlands and riparian).

Water quality

The Soos Creek Subbasin is transitional, ranging from dense residential development on the eastern edge to mostly forested land cover, low density residential, and hobby farms. Because of this gradation, the subbasin displayed a wide variety of water quality conditions. Most of the properly function DAUs in the Soos Creek subbasin were protected areas, such as the Lake Youngs water supply (DAU 4) and the upper Soos Creek wetlands complex. SR-18 and SR-516 both contribute pollutants to the Soos Creek subbasin.

Fish resources

Chinook, coho, steelhead, pink, sockeye, and cutthroat spend one or more parts of their life cycle in this subbasin.

Chinook are found in Soos Creek, Soosette Creek, Covington Creek (reported below), Jenkins Creek (reported below) and Little Soos Creek. Coho, steelhead, and cutthroat utilize these streams as well, though will generally penetrate farther upstream; coho and cutthroat also utilize several smaller, unnamed tributaries. Pink salmon and sockeye are found only in the lowermost reach of Soos Creek.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Soos Creek and its tributaries in the Soos Creek Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Soos Creek Subbasin is a mix of DAUs in an "at risk" and a "not properly functioning" condition for the delivery of water. A large cluster of 10 DAUs in the northeast part of the subbasin and four DAUs in the southern are considered to be in an "at risk" condition, while the Covington area and DAUs to the northwest are "not properly functioning (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Soos Creek and its tributaries in the Soos Creek Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the Soos Creek Subbasin is in an "at risk" condition for the delivery of sediment. The lone exception is the Lake Youngs DAU that is considered to be "properly functioning" (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Soos Creek and its tributaries in the Soos Creek Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Soos Creek Subbasin is a mix of DAUs in an "at risk or a "not properly functioning" condition for the delivery and routing of large wood. One small DAU near the eastern edge of the subbasin is considered to be in a "properly functioning" condition (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the Soos Creek and its tributaries in the Soos Creek Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Soos Creek Subbasin can be subdivided into a three large areas when evaluating aquatic integrity. The southern and northeastern parts of the subbasin are considered to be in an "at risk" condition, while the central and northwest parts of the subbasin are considered to be in a "not properly functioning" condition for aquatic integrity (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 34 percent (6,704 total forested acres) of the Soos Creek Subbasin. Much of the remaining forest cover is concentrated around Lake Youngs and along the riparian corridors such as Soos Creek, the remainder scattered around the plateau, fragmented by urban and agricultural land use (Figure 58, “Upland Forest Cover”). The Soos Creek Subbasin is considered “at risk” for upland forest cover with a median probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Fennel Creek Subbasin?

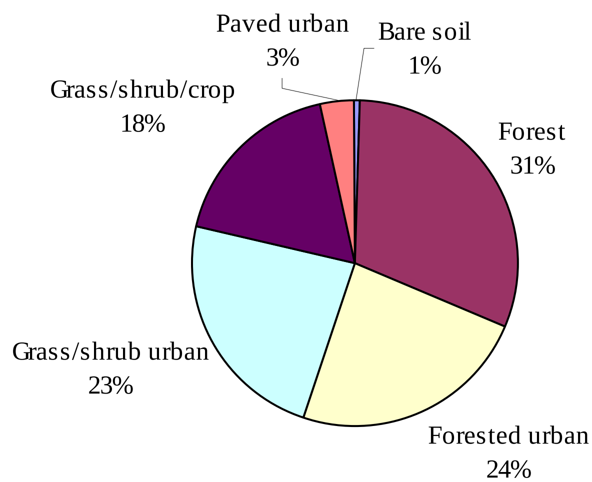
The Fennel Creek Subbasin drains a lobe of the Osceola mudflow and the adjoining drift plain south and east of the City of Bonney Lake (see Figure 22, Fennel Creek Subbasin). The creek flows west and south through a former glacial meltwater channel to Victor Falls, continuing west through a steep canyon and across the Puyallup Valley floor to its confluence with the Puyallup River. Total subbasin area is 8,580 acres (13.4 sq. mi.). There are no significant tributaries to Fennel Creek.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Based on 1998 LANDSAT imagery, the Fennel Creek subbasin is split evenly between urban (50 percent) and non-urban (50 percent) land covers (see Figure 21, Current Land Use in the Fennel Creek Subbasin). Moderate-to-high density residential and commercial development occurs within and to the south of the city of Bonney Lake. Agriculture, forest, and rural residential land uses occur over the rest of the subbasin, generally coinciding with volcanic mudflow deposits along Fennel Creek and between the cities of Bonney Lake and Buckley.



Land cover data from 1998 Landsat images.

Figure 21. Current Land Use in the Fennel Creek Subbasin.

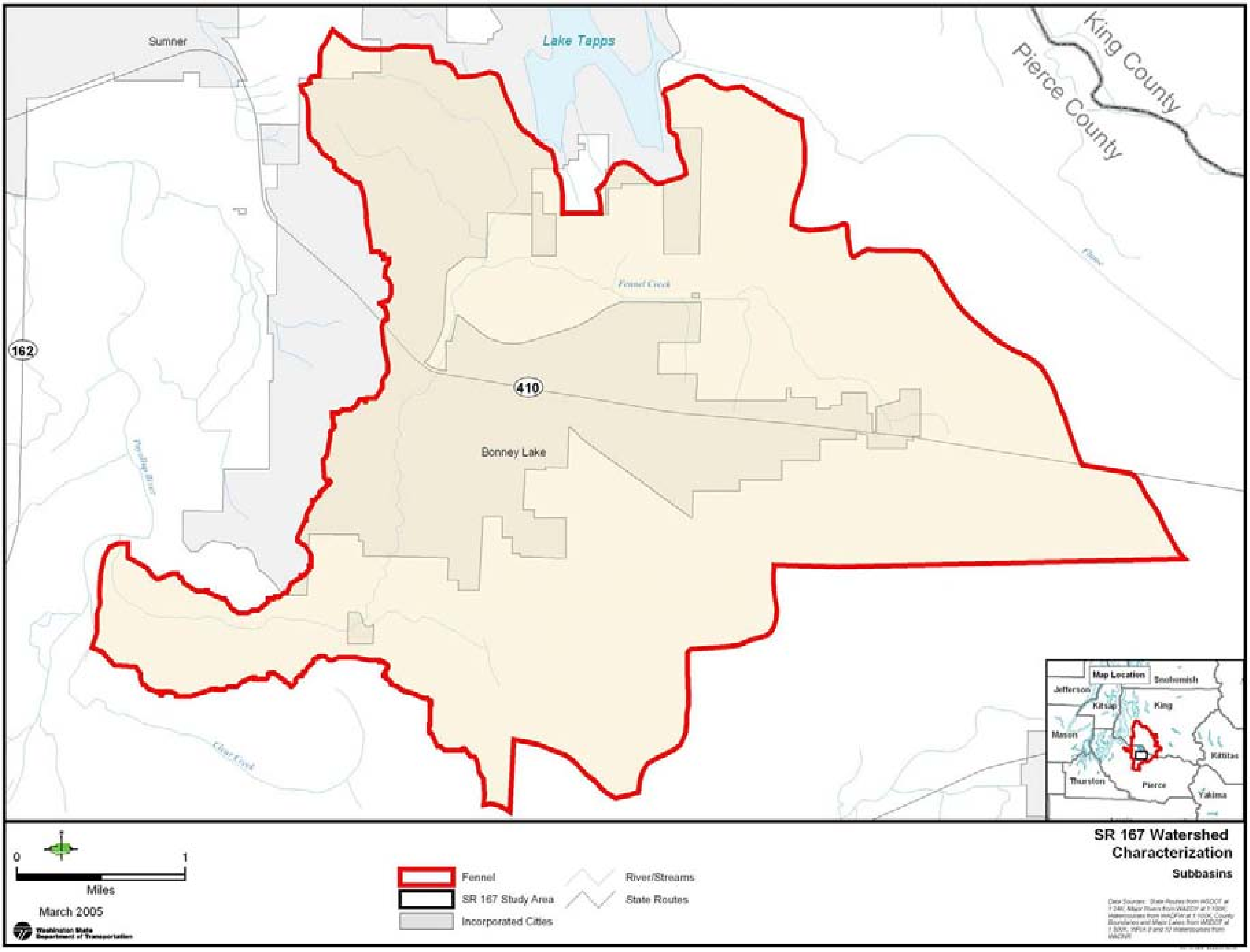


Figure 22. Fennel Creek Subbasin.

Future conditions

Future land use in the Fennel Creek Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 32 percent to 37 percent.

Hydrogeology and groundwater recharge

Upland areas of the subbasin consist of till and thick outwash deposits, which are mantled along the eastern portion of the subbasin by mudflow deposits. The glacial meltwater channel within which Fennel Creek flows to the Puyallup valley consists of outwash delta deposits mantled by mudflow deposit to Victor Falls. Victor Falls is a 90 foot high waterfall formed by an older, indurated (cemented) mudflow deposit which serves as a capstone. Below Victor Falls the creek is deeply incised into outwash deposits. At the outlet of the canyon, the creek flows across an alluvial fan which extends a short distance onto the Puyallup valley floor.

Soils established on till and mudflows convey storm flow rapidly as surface drainage. Some surface runoff infiltrates into outwash deposits, where it may be conveyed to seepage zones lining the margins of the canyon reach or the east side of the Puyallup valley. These seepage zones serve as an important water source for wetlands and small tributaries found on the valley floor. Outwash deposits cover 16 percent of the subbasin, primarily in upland areas to the north and south of the valley. Approximately 34 percent of these important groundwater recharge areas are now covered by impervious surfaces.

The Fennel Creek alluvial fan is included as a part of a Pierce County Critical Aquifer Recharge area.

Runoff and streamflow

Fennel Creek originates on the drift plain between the cities of Buckley and Bonney Lake. No long term gaging information is available for the site.

The upper portion of the creek is extensively ditched and channelized to accommodate agricultural and urban development activities. Beginning just above the SR-410 crossing, the creek is relatively unencumbered and has developed a meander pattern down to Victor Falls. Below Victor Falls, the creek is not channelized, but is confined between steep canyon walls. At the outlet of the canyon, the channel again has levees which extend to its confluence with the Puyallup River.

Increased urbanization is occurring within the subbasin, almost entirely on the upland drift plain. TIA is estimated to be approximately 32 percent.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Fennel Creek Subbasin totaled approximately 2,810 acres and represented 33 percent of the subbasin. Of this pre-development total, we estimate that 2,773 acres (32 percent of subbasin) were wetlands and 37 acres (less that one percent of subbasin) were natural deepwater lakes. We estimate that approximately 1,209 acres, or 14 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty-four percent of the original 2,773 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 348 acres of wetlands in the Fennel Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 29 percent of all existing or potential wetlands (1,209 acres) and 13 percent of all historic wetlands (2,773 acres). Fifty-seven percent (687 acres) of the 1,209 acres of current or potential wetlands have evidence of hydrologic alteration, while 70 percent (844 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 861 acres (71 percent) of the 1,209 current or potential wetland acres in the Fennel Creek Subbasin are considered altered.

Of the 1,209 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Fennel Creek Subbasin include 809 acres of depressional wetlands (67 percent) and 361 acres of riverine wetlands (30 percent). Anadromous fish are estimated to have access to two percent (19 acres) of the 1,246 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on half of the 67-meter wide riparian corridors in the Fennel Creek basin, but there are still some forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Of the 736 total acres, 49 percent, or 361 acres, of the riparian zone remain forested, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, nine areas comprising 48 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of considerable size were evaluated in the Fennel Creek subbasin for this study as the total original floodplain acreage was only 36 acres. This has been reduced to 29 acres today, a reduction of only 21 percent. Potential restoration sites were evaluated in terms of potential habitat, wetland, and/or riparian functions. (see sections on wetlands and riparian).

Water quality

The Fennel Creek subbasin currently has two predominant land covers. One is the urbanizing area centered on the city of Bonney Lake and SR-410 in the north. The Bonney Lake plateau in the south is currently undeveloped but slated for development in the near future. Soils in the Fennel Creek subbasin are generally mixed, discontinuous patches of outwash and till. Large portions of the subbasin are being rapidly developed within the Bonney Lake urban growth area, therefore runoff characteristics are rapidly changing. SR-410 contributes runoff and pollutants to the Fennel Creek subbasin.

Fish resources

Chinook, coho, steelhead, pink, and cutthroat utilize the lower two miles of Fennel Creek, below Victor Falls.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Fennel Creek and its tributaries in the Fennel Creek Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Fennel Creek Subbasin is divided evenly between DAUs considered to "at risk" and "not properly functioning". Within this subbasin, the two southwestern and two northeastern DAUS are considered to be "at risk" for the delivery of water (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Fennel Creek and its tributaries in the Fennel Creek Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Fennel Creek Subbasin is in an "at risk" condition for the delivery of sediment (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Fennel Creek and its tributaries in the Fennel Creek Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Fennel Creek Subbasin is a mix of DAUs in an "at risk" or a "not properly functioning" condition for the delivery and routing of large wood (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the Fennel Creek and its tributaries in the Fennel Creek Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Fennel Creek Subbasin is a mix of DAUs in an "at risk" or a "not properly functioning" condition for aquatic integrity. A core area of four DAUs immediately south of Lake Tapps is considered "not properly functioning," while the remaining four DAUs are in an "at risk" condition (Figure 56, "Condition Map for Aquatic Integrity," and Figure 57, "Overall Condition map for Aquatic Integrity").

Upland forest cover

Forest covers 30 percent (2,592 total forested acres) of the Fennel Creek Subbasin. Most of the remaining forest lies along riparian corridors, including a section along the Fennel Creek canyon that is part of a larger forest complex along the plateau above the Carbon River, connected to a large section of forest in the South Prairie Creek Subbasin (Figure 58, “Upland Forest Cover”). Due to the otherwise widely dispersed forest cover in the Fennel Creek Subbasin, it is considered “not properly functioning” for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Lake Tapps Subbasin?

The Lake Tapps subbasin includes all areas draining to Lake Tapps, including the diversion canal (see Figure 24, Lake Tapps Subbasin). Total subbasin area is 10,918 acres (17.1 sq. mi.). There are no significant tributaries.

Pre-development land cover

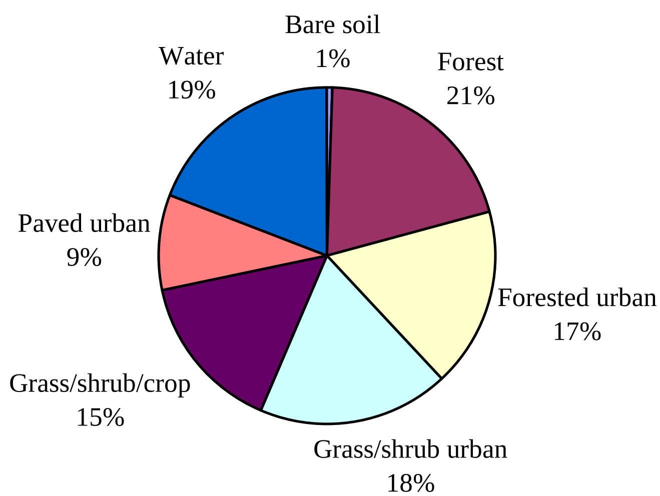
Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Based on 1998 LANDSAT imagery, the Lake Tapps subbasin is comprised primarily of urban (44 percent) land covers, followed by forest (21 percent), open water (19 percent) and grass/shrub/crop (15 percent) land covers (see Figure 23, Current Land Use in the Lake Tapps Subbasin). Urban land covers are concentrated near the lake.

Future conditions

Future land use in the Lake Tapps Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 38 percent to 44 percent.



Land cover data from 1998 Landsat images.

Figure 23. Current Land Use in the Lake Tapps Subbasin.

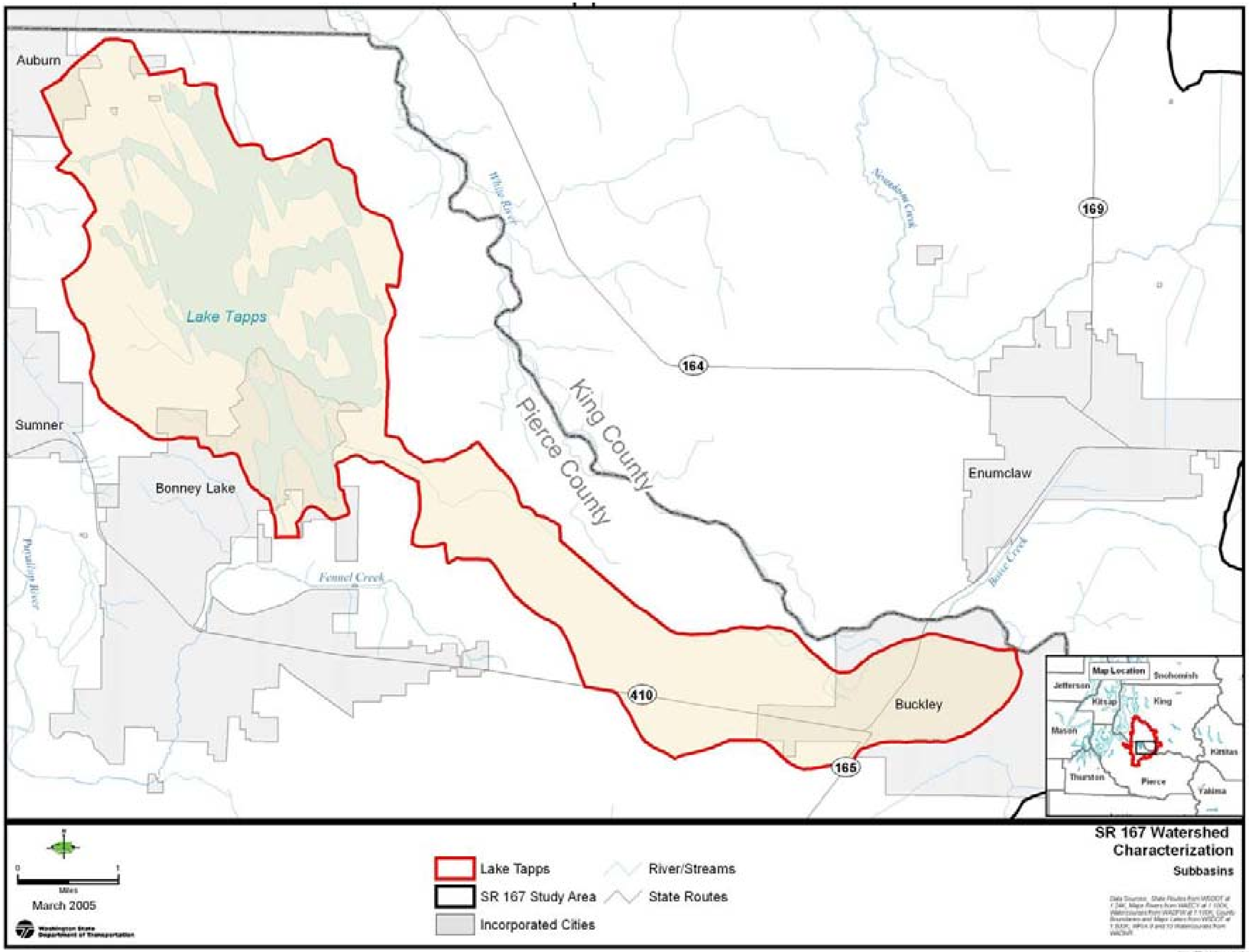


Figure 24. Lake Tapps Subbasin.

Hydrogeology and groundwater recharge

The Lake Tapps subbasin is underlain by till and mudflow deposits. Soils established on till and mudflows convey storm flow rapidly as surface drainage, forming small creeks that drain into Lake Tapps. Infiltration and groundwater recharge is believed to be limited compared to other subbasins, owing to the absence of permeable outwash on the surface of the subbasin. Seepage from Lake Tapps through till deposits is believed to enhance discharge from springs occurring in down-gradient outwash deposits along the valley margin of the White River.

Runoff and streamflow

Lake Tapps was created in 1911 by constructing a series of dikes to expand four naturally occurring lakes. Lake inflow is primarily via diversion from the White River (RM 24.3); local flow contributions are minor. Lake outflow is primarily via a tunnel to the White River Powerhouse, which discharges to the White River at RM 3.6.

The area around the lake is becoming increasingly urbanized. TIA is estimated to be approximately 30 percent based on 1998 Landsat imagery.

Wetlands

Lake Tapps is a man-made lake. However, for our characterization work, we are considering it to be a permanent aquatic feature and include it as a natural deepwater lake system. Prior to human alteration, wetlands and deepwater lakes within the Lake Tapps subbasin totaled approximately 6,646 acres and represented 61 percent of the subbasin. Of this pre-development total, we estimate that 4,040 acres (37 percent of subbasin) were wetlands and 2,605 acres (24 percent of subbasin) were natural deepwater lakes. We estimate that approximately 1,208 acres, or 11 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Thirty percent of the original 4,040 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 241 acres of wetlands in the Lake Tapps Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 20 percent of all existing or potential wetlands (1,208 acres) and six percent of all historic wetlands (4,040 acres). Seventy-five percent (903 acres) of the 1,208 acres of current or potential wetlands have evidence of hydrologic alteration, while 80 percent (967 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 967 acres (80 percent) of the 1,208 current or potential wetland acres in the Lake Tapps Subbasin are considered altered.

Of the 1,208 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lake Tapps Subbasin include 1,104 acres of depressional wetlands (91 percent) and nine acres of riverine wetlands (one percent). Anadromous fish have no access to natural or manmade deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on much of the 67-meter wide riparian corridors in the Lake Tapps basin, but there are still significant forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Fifty-six percent of the riparian zone remains forested, or 384 acres of 686 total acres, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, only two areas comprising nine acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of considerable size were evaluated in the Lake Tapps Subbasin for this study. Potential restoration sites in floodplain areas for this subbasin were evaluated in terms of potential aquatic habitat, wetland, and/or riparian functions (see sections on wetlands and riparian).

Water quality

The Lake Tapps Subbasin is unusual in that most of the land cover consists of Lake Tapps itself and a thin strip of land that lies on either side of the White River diversion canal. The land surrounding the lake consists almost entirely of dense residential developments with intermittent park lands directly abutting the lakeshore. Due to direct precipitation inputs to the lake, Lake Tapps model results are dominated by direct precipitation to lake waters.

Fish resources

There is no fish utilization of the Lake Tapps Subbasin.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Lake Tapps and its tributaries in the Lake Tapps Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the DAUs associated with Lake Tapps are considered “not properly functioning” for the delivery of water, while two of three DAUs to the east of the lake, associated with the water supply are considered to be “at risk” for the movement of water. The easternmost DAU consists primarily of the town of Buckley, and is considered to be in a “not properly functioning” condition (Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Lake Tapps and its tributaries in the Lake Tapps Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Lake Tapps Subbasin is in an “at risk” condition for the delivery of sediment (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Lake Tapps and its tributaries in the Lake Tapps Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Lake Tapps Subbasin is a mix of DAUs considered to be in an “at risk” or a “not properly functioning” condition for the delivery and routing of large wood (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Lake Tapps and its tributaries in the Lake Tapps Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Lake Tapps Subbasin is primarily in a “not properly functioning” condition for aquatic integrity. Exceptions include two of the three DAUs making up the elongated area of the subbasin east of the lake that are considered to be in an “at risk” condition (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Most of the Lake Tapps Subbasin is covered by Lake Tapps, but of the upland area forest covers 24 percent (2,119 total forested acres) of the subbasin (Figure 58, “Upland Forest Cover”). Due to the widely dispersed forest cover in the Lake Tapps Subbasin, it is considered “not properly functioning” for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Lower Carbon River Subbasin?

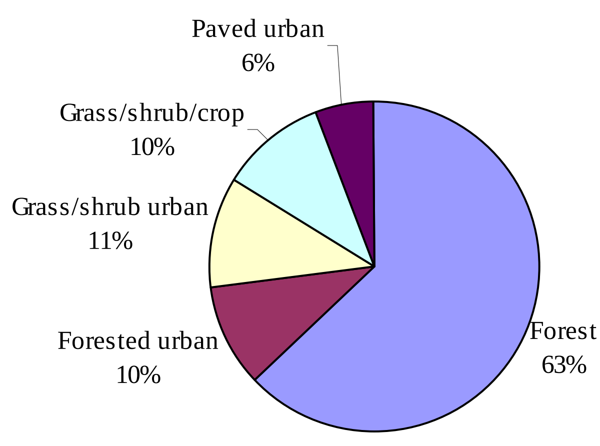
The Lower Carbon Subbasin includes all areas draining to the Carbon River below the confluence with South Prairie Creek (RM 5.7), excluding portions to the south that lie outside the study area (see Figure 26, Lower Carbon River Subbasin). Total subbasin area is 3,927 acres (6.14 sq. mi.). The only significant tributary within the subbasin is Voight Creek.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Based on 1998 LANDSAT imagery, the Lower Carbon River Subbasin is comprised primarily of forest land cover (63 percent); urban land covers account for 27 percent of the subbasin area. Most of the higher-density development occurs in and around the city of Orting (see Figure 25, Current Land Use in the Lower Carbon River Subbasin). The valley floor of the Carbon River outside of Orting has primarily agricultural and rural residential land use. The upland area is currently mostly forested, with a small amount of rural residential development. Development of a proposed master planned community is expected to convert much of the remaining forested and upland area to moderate- and high-density residential and commercial land use.



Land cover data from 1998 Landsat images.

Figure 25. Current Land Use in the Lower Carbon River Subbasin.

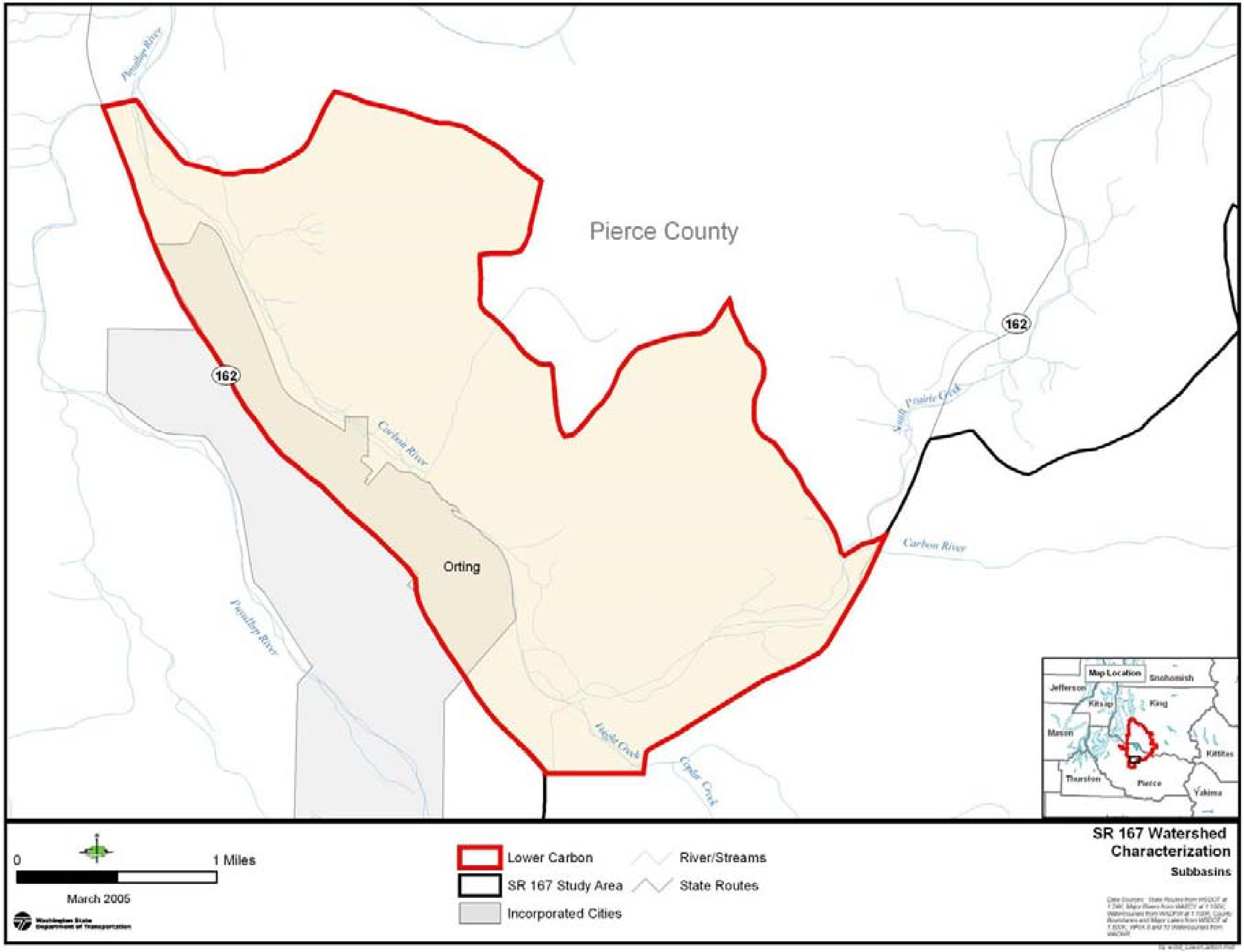


Figure 26. Lower Carbon River Subbasin.

Future conditions

Future land use in the Lower Carbon Subbasin is predicted to reflect a sharp increase in urban character, with residential and commercial development increasing the TIA from 20 percent to 37 percent, a 84 percent increase. While some of this change is due to development within the city limits of Orting, mush is related to the planned development of Cascadia.

Hydrogeology and groundwater recharge

Approximately 40 percent of the subbasin area lies on the valley floor, which consists of alluvium and mudflow deposits laid down since the last glacial advance. Upland areas consist of till and thick outwash deposits. Soils established on till convey storm flow rapidly as surface drainage, forming small creeks that cut steep ravines as they descend to the valley floor. Some surface runoff infiltrates into outwash deposits, where it may be conveyed to seepage zones lining the valley margins; these seepage zones serve as an important water source for wetlands and small tributaries found on the valley floor. Outwash deposits cover 30 percent of the subbasin, primarily in upland areas to the east and west of the valley. Approximately six percent of these important groundwater recharge areas are now covered by impervious surfaces.

Valley floor deposits are included as a part of a Pierce County Critical Aquifer Recharge area.

Runoff and streamflow

The Carbon River originates on the Carbon Glacier on the north flank of Mt. Rainier and flows through the Cascade range for approximately 26 miles to the study area boundary.

Upstream of the subbasin, the channel varies from relatively flat, braided channels to high gradient canyon reaches. Sediment storage and transport rates in the river are naturally high due to the glacial source. Human impacts on the river over this distance are very minor.

Total watershed area at the long-term USGS stream gage located about 12 miles upstream from the study area boundary (12094000 – Carbon River near Fairfax) is 79 square miles. Mean annual discharge at this gage is 427 cfs.

Within the subbasin, the left bank of the river is diked over its entire length, and the right bank over lower 1.2 miles; some channel braiding occurs between town of Orting and the confluence with South Prairie Creek.

Increased urbanization is occurring within the subbasin, both on the valley floor and on the upland drift plain. TIA is estimated to be approximately 20 percent.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Lower Carbon Subbasin totaled approximately 366 acres and represented nine percent of the subbasin. Of this pre-development total, we estimate that all 366 acres were wetlands. No natural deepwater lakes were noted. We estimate that approximately 285 acres, or seven percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Seventy-eight percent of the original 366 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 165 acres of wetlands in the Lower Carbon Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 58 percent of all existing or potential wetlands (285 acres) and 45 percent of all historic wetlands (366 acres). Forty-one percent (117 acres) of the 285 acres of current or potential wetlands have evidence of hydrologic alteration, while 33 percent (95 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 121 acres (42 percent) of the 285 current or potential wetland acres in the Lower Carbon Subbasin are considered altered.

Of the 285 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower Carbon Subbasin include five acres of depressional wetlands (one percent) and 275 acres of riverine wetlands (96 percent). Anadromous fish are estimated to have access to 96 percent (274 acres) of the 285 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the Lower Carbon River basin, but there are still significant forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Eighty-three percent of the riparian zone remains forested, or 532 acres of 642 total acres, though road crossings have disconnected some of these areas. Of the non-forested riparian corridor, six areas comprising 73 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

Most of the remaining floodplain area in the Carbon River Subbasin occurs in the 4-mile reach in the vicinity of Orting. The steep gradient of the river upstream of Orting results in high velocities that erode the banks, causing channel changes during high flows. Channel capacity in the vicinity of Orting is estimated at 6,000 cfs (Federal Emergency Management Agency, 1987). Of the 1,426 acres of original floodplain in the Lower Carbon River subbasin, only 39 acres remain, a reduction in area of 97 percent. Remaining floodplain areas along the Carbon are under considerable development pressure.

Water quality

The Lower Carbon River subbasin is the smallest in the study area, with only 3 DAUs. Soils are a combination of mudflow deposits and poorly draining alluvium. Land cover is predominantly forest with a mixture of dense residential development within the city of Orting and adjacent agricultural land covers. Runoff volumes are moderate since the tight resident soils tends to hydrologically cancel out the predominantly forested land cover. SR-162 is the only state highway contributing runoff and pollutants to the subbasin.

Fish resources

Chinook, coho, steelhead, pink, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. All species utilize the mainstem Carbon, primarily as a migration corridor for adults returning to spawning areas further upstream and for juveniles traveling to the ocean.

Chinook are found primarily in the mainstem Carbon, but also in Voight Creek and the valley floor reaches of an unnamed tributary at river mile 4.5. Coho, cutthroat, and pink salmon also utilize these tributaries, while steelhead are found in Voight Creek.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Lower Carbon River and its tributaries in the Lower Carbon Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the entire Lower Carbon Subbasin is in an “at risk” condition for the delivery of water (Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Lower Carbon River and its tributaries in the Lower Carbon Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the Lower Carbon Subbasin consists of a mix of DAUs in an “at risk” and a “properly functioning” condition for the delivery of sediment. The westernmost DAU is considered “properly functioning, while the two eastern DAUs are “at risk” (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Lower Carbon River and its tributaries in the Lower Carbon Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the entire Lower Carbon Subbasin is in an “at risk” condition for the delivery and routing of large wood (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Lower Carbon River and its tributaries in the Lower Carbon Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the entire Lower Carbon Subbasin is in an “at risk” condition for aquatic integrity (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 62 percent (2,447 total forested acres) of the Lower Carbon River Subbasin. The valley portion of the subbasin, on the west side, is almost devoid of forest, and the remaining forest is concentrated on the plateau, part of a larger forest complex that spreads into the Mid Puyallup North, Fennel Creek, and South Prairie Creek subbasins (Figure 58, “Upland Forest Cover”). Due to the high concentration of forest cover in most of the subbasin, the Lower Carbon River Subbasin is the only subbasin considered “properly functioning” for upland forest cover and there is a relatively high probability that the subbasin can support habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Lower White East Subbasin?

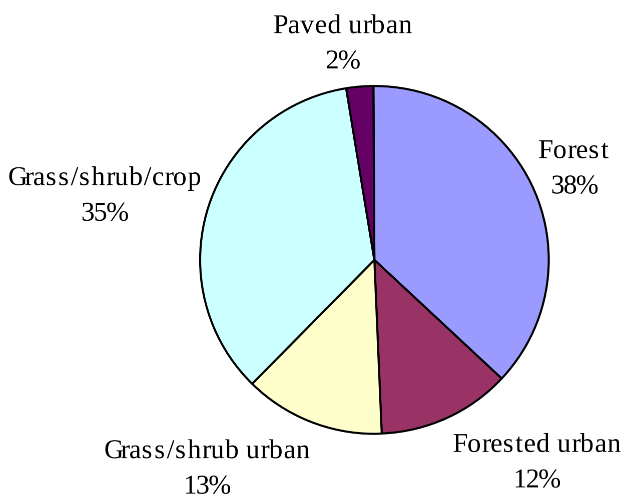
The Lower White East Subbasin includes all areas draining to the White River from the confluence with Red Creek near Buckley (RM 27.5) downstream to approximately river mile 12, except for areas within the Lake Tapps Subbasin, which is reported separately (see Figure 28, Lower White East Subbasin).. Total subbasin area is 20,956 acres (32.7 sq. mi.). The only significant tributary within the subbasin is Boise Creek.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Based on 1998 LANDSAT imagery, the Lower White East Subbasin is comprised primarily of forest (38 percent) and grass/shrub/crop (35 percent) land cover; urban land covers account for 27 percent of the subbasin area (see Figure 27, Current Land Use in the Lower White East Subbasin). Land cover in the White River Valley is predominantly forest. Upland areas are primarily agriculture and rural residential land use, with moderate- and high-density residential and commercial development within the city of Enumclaw.



Land cover data from 1998 Landsat images.

Figure 27. Current Land Use in the Lower White East Subbasin.

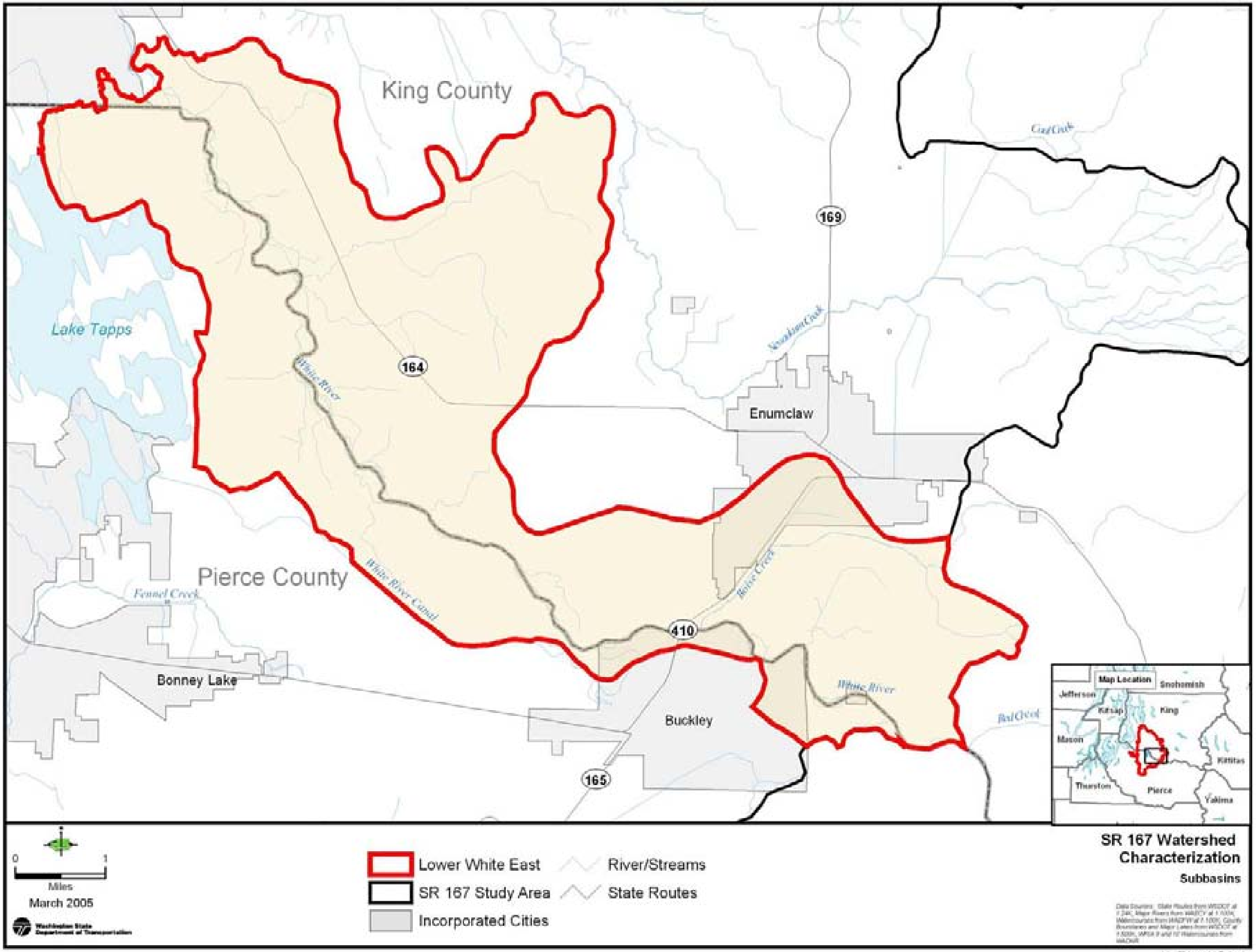


Figure 28. Lower White East Subbasin.

Future conditions

Future land use in the Lower White East Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 20 percent to 23 percent.

Hydrogeology and groundwater recharge

Approximately 20 percent of the subbasin area lies on the White River valley floor, which consists of alluvial deposits laid down since the last glacial advance. The "upland" area consists of a broad, flat plain composed of extensive mudflow deposits, with sporadic exposures of till and bedrock projecting above the plain. Soils established on till and mudflows convey storm flow rapidly as surface drainage, forming small creeks that cut steep ravines as they descend to the valley floor. Infiltration and groundwater recharge is believed to be limited compared to other subbasins, owing to the absence of permeable outwash on the upland plain. Outwash deposits cover just two percent of the subbasin, primarily along valley margins. Approximately seven percent of these important groundwater recharge areas are now covered by impervious surfaces.

Runoff and streamflow

The White River originates at the terminus of the Winthrop, Fryingpan and Emmons glaciers on the slopes of Mt. Rainier. It flows through the Cascade range for approximately 48 miles to the study area boundary. Total watershed area at the long-term USGS stream gage located within the subbasin (12098500 –White River near Buckley) is 401 square miles. Mean annual discharge at this gage is 1,435 cfs. Mud Mountain Dam (RM 29.5) is operated by the U.S. Army Corps of Engineers for the purpose of flood control, and limits peak flows at Buckley to less than 15,000 cfs (compared to a pre-dam maximum peak of 28,000 cfs). The White River Hydroelectric Project diversion dam at RM 24.3 has diverted up to 2,000 cfs from the White River to Lake Tapps for hydropower generation, typically leaving only 130-150 cfs in the river in the "bypass reach" (RM 24.3 to RM 3.6) during most of the year. Recent modifications in the operation of this project have resulted in increases in minimum flows in the bypass reach to between 250 and 400 cfs, depending on time of year.

Channel modification only occurs at, and in the vicinity of, the diversion dam at RM 24.3. Otherwise, the river appears to be constrained laterally only by the valley walls. However, sediment retention and peak flow truncation by Mud Mountain Dam have resulted in the development of an armored channel, which limits channel mobility.

Increased urbanization is occurring within the subbasin, almost exclusively on the upland plain. TIA is estimated to be approximately 20 percent based on 1998 Landsat imagery.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Lower White East Subbasin totaled approximately 11,819 acres and represented 57 percent of the subbasin. Of this pre-development total, we estimate that 11,806 acres (57 percent of subbasin) were wetlands and 13 acres (less than one percent of subbasin) were natural deepwater lakes. We estimate that approximately 5,672 acres, or 27 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty-eight percent of the original 11,806 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 2,766 acres of wetlands in the Lower White East Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 49 percent of all existing or potential wetlands (5,672 acres) and 23 percent of all historic wetlands (11,806 acres). Fifty percent (2,841 acres) of the 5,672 acres of current or potential wetlands have evidence of hydrologic alteration, while 50 percent (2,848 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 2,907 acres (51 percent) of the 5,672 current or potential wetland acres in the Lower White East Subbasin are considered altered.

Of the 5,672 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower White East Subbasin include 2,917 acres of depressional wetlands (51 percent) and 2,747 acres of riverine wetlands (48 percent). Anadromous fish are estimated to have access to 58 percent (3,300 acres) of the 5,685 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the Lower White River East basin, but there are still significant forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Sixty-two percent of the riparian zone remains forested, or 1,839 acres of 2,938 total acres, though road crossings have disconnected some of these areas. Most of the riparian forest lies along the White River canyon or on steep slopes. Of the non-forested riparian corridor, 36 areas comprising 353 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The flows of the White River formerly split, with a portion flowing north to Elliot Bay via the Green River. In 1906, a natural channel avulsion cut off this channel and the entire White River flowed down what was previously known as the Stuck River into the Puyallup River. This channel modification was reinforced by levees and other floodworks by 1916. In addition, the Mud Mountain Dam, located at RM 29.6, reduces peak flow on the White to 20,000 cfs, and numerous levees have changed the flood inundation areas and eliminated much of the White River’s original floodplain.

As with most of the other subbasins in the study area, flood control activities have reduced the hydrograph, and narrowed and simplified the channel. Of 3,903 acres of original floodplain in the Lower White East and subbasin, only 1,452 acres remain in the FEMA floodplain jurisdiction today, representing a 63 percent reduction in historic floodplain area.

Water quality

The runoff and pollutant loss characteristics of the Lower White River East Subbasin is largely defined by the large areas of very low permeability mudflow deposits created by an eruption of Mount Rainier about 5,400 years ago. Almost the entire subbasin is covered by these deposits. There are significant areas of agricultural land, but little urbanization.

Fish resources

Chinook, coho, steelhead, pink, sockeye, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. All species utilize the mainstem White, primarily as a migration corridor for adults returning to spawning areas further upstream and for juveniles traveling to the ocean.

Chinook are found primarily in the mainstem White and larger tributaries (Boise Creek, unnamed tributaries at river mile 15.4, 15.5 and 17.2). Coho, cutthroat and steelhead will utilize the same tributaries, though will generally penetrate farther upstream. In addition to the mainstem, pink salmon and sockeye will utilize Strawberry Creek.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Lower White River and its tributaries in the Lower White East Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Lower White East Subbasin is primarily in an "at risk" condition for the delivery of water. Exceptions include two DAUs in the eastern part of the subbasin associated with the towns of Buckley and Enumclaw that are considered to be in a "not properly functioning" condition (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Lower White River and its tributaries in the Lower White East Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the Lower White East Subbasin is primarily in an "at risk" condition for the delivery of sediment. The lone exception is a DAU on the southeastern edge of the subbasin that is considered to be in a "not properly functioning condition (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Lower White River and its tributaries in the Lower White East Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Lower White East Subbasin has a mix of condition ranks for the delivery and routing of large wood. Three DAUs are considered to be "properly functioning," seven DAUs are considered to be "at risk," and five DAUs are considered to be in a "not properly functioning" condition (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the Lower White River and its tributaries in the Lower White East Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Lower White East Subbasin is predominantly in an "at risk" condition for aquatic integrity. The one exception is a DAU, associated with the town of Enumclaw, considered to be in a "not properly functioning condition (Figure 56, "Condition Map for Aquatic Integrity," and Figure 57, "Overall Condition map for Aquatic Integrity").

Upland forest cover

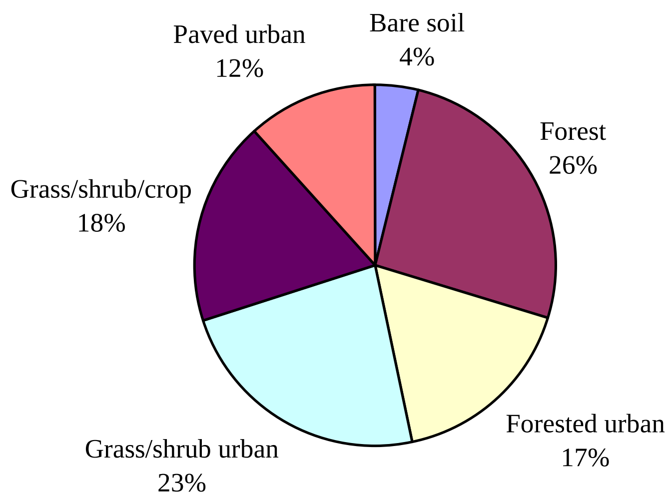
Forest covers 37 percent (7,611 total forested acres) of the Lower White River East Subbasin. Most of the remaining forest lies along the White River's riparian corridor, and forms a structurally connected forest strip from the study area boundary to the Green River Valley, connected at a pinch point to the Middle Green River's main forest cover patch (Figure 58, "Upland Forest Cover"). Due to the otherwise widely dispersed forest cover along the Enumclaw Plateau in the Lower White River East Subbasin, it is considered "at risk" for upland forest cover and has a median probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, "Final Condition Map for Forest Density Areas").

What conditions did we find in the Lower White West Subbasin?

The Lower White West Subbasin includes all areas draining to the White River from approximately river mile 12 to the confluence with the Puyallup River near Sumner, except for areas within the Lake Tapps Subbasin, which is reported separately (see Figure 30, Lower White West Subbasin). Total subbasin area is 16,359 acres (25.6 sq. mi.). Significant tributaries within the subbasin include Strawberry (Salmon Springs) Creek, Bowman Creek, and an unnamed ditch draining the west side of the White River Valley between Sumner and Auburn.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.



Land cover data from 1998 Landsat images.

Figure 29. Current Land Use in the Lower White West Subbasin.

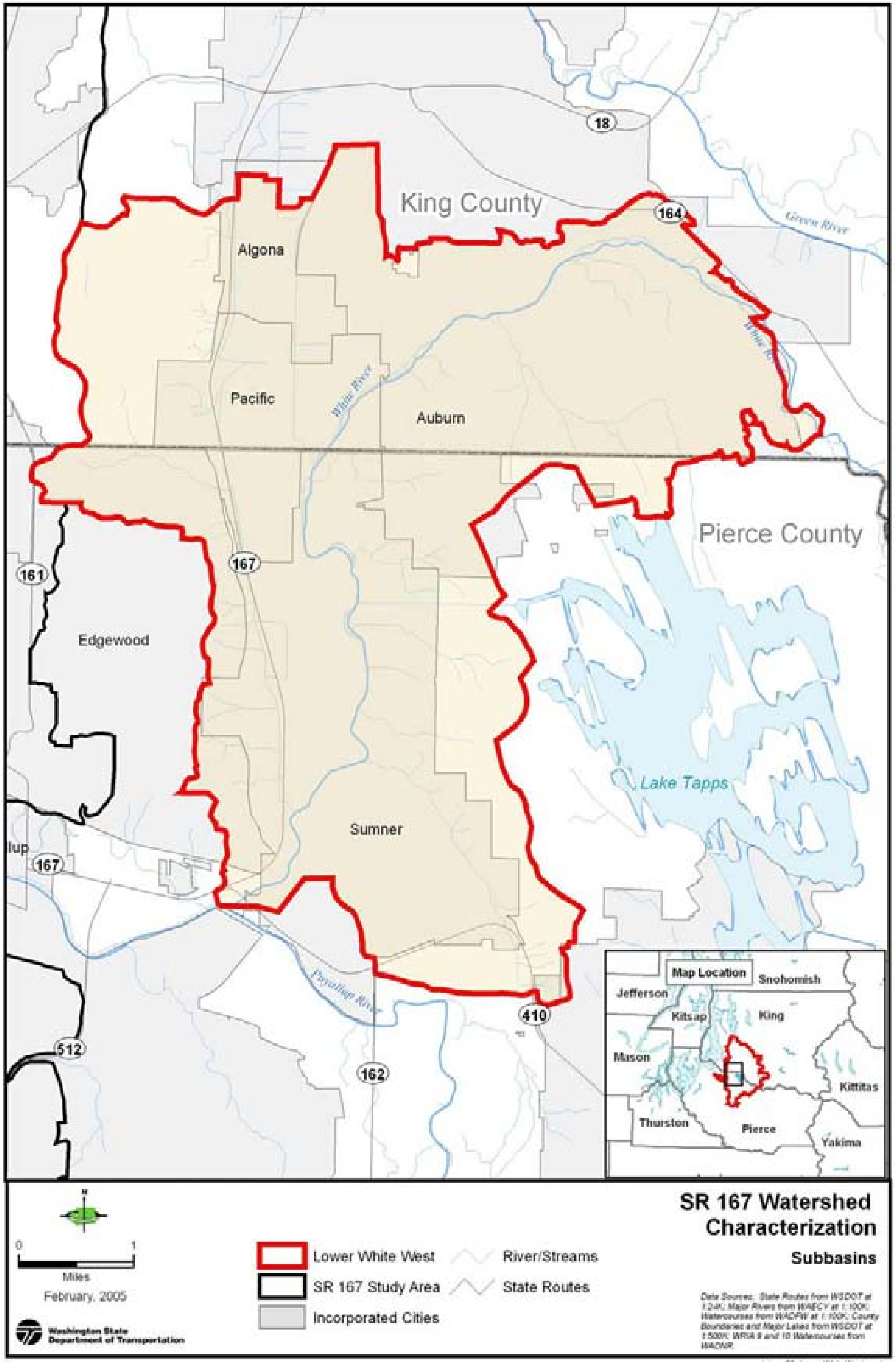


Figure 30. Lower White West Subbasin.

Current conditions

Based on 1998 LANDSAT imagery, the Lower White West Subbasin is split evenly between urban (52 percent) and non-urban (48 percent) land covers (see Figure 29, Current Land Use in the Lower White West Subbasin). The most intense commercial and industrial land uses occur within the cities of Auburn, Algona, Pacific, and Sumner. The valley floor of the White River is primarily agricultural and rural residential land use between Auburn and Sumner; land cover is predominantly forest above Auburn. Moderate- to high-density residential and commercial development occurs over much of the rest of the valley, and is interspersed with forest in the upland areas.

Future conditions

Future land use in the Lower White West Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 40 percent to 49 percent.

Hydrogeology and groundwater recharge

Approximately 40 percent of the Lower White West Subbasin lies on the White River valley floor, which consists of alluvial deposits laid down since the last glacial advance. Upland areas consist of till and thick outwash deposits. Soils established on till and mudflows convey storm flow rapidly as surface drainage, forming small creeks that cut steep ravines as they descend to the valley floor. Some surface runoff infiltrates into outwash deposits, where it may be conveyed to seepage zones lining the valley margins. These seepage zones serve as an important water source for wetlands and small tributaries found on the valley floor. Outwash deposits cover 17 percent of the subbasin, primarily in upland areas to the east and west of the valley. Approximately 33 percent of these important groundwater recharge areas are now covered by impervious surfaces.

Valley floor deposits south of the county line are included as a part of a Pierce County Critical Aquifer Recharge area.

Runoff and streamflow

The White River originates at the terminus of the Winthrop, Fryingpan and Emmons glaciers on the slopes of Mt. Rainier and flows through the Cascade range for approximately 48 miles to the study area boundary. Total watershed area at the long-term USGS stream gage located within the subbasin (12100500 –White River near Sumner) is 470 square miles. Mean annual discharge at this gage is 616 cfs. Two in-stream structures have a significant effect on flow quantity and timing in this subbasin. Mud Mountain Dam (RM 29.5) is operated by the U.S. Army Corps of Engineers for the purpose of flood control, and limits peak flows at Buckley to less than 15,000 cfs (compared to a pre-dam maximum peak of 28,000 cfs); effects of this facility on mean annual discharge are negligible because all water stored during flood events is released immediately afterwards. The White River Hydroelectric Project diversion dam at RM 24.3 has diverted up to 2,000 cfs from the White River to Lake Tapps for hydropower generation, typically leaving only 130-150 cfs in the river in the “bypass reach” (RM 24.3 to RM 3.6) during most of the year. Recent modifications in the operation of this project have resulted in increases in minimum flows in the bypass reach to between 250 and 400 cfs, depending on time of year.

The White River is channelized between levees along both banks from the confluence with the Puyallup River upstream to RM 8.5. Levees and revetments within the Muckleshoot Indian Reservation (RM 8.5 to RM 12) have been allowed to breach naturally by the White River in an effort to restore natural river channel sinuosity.

Increased urbanization is occurring within the subbasin, both on the valley floor and on the upland drift plain. TIA is estimated to be approximately 40 percent based on 1998 Landsat imagery.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Lower White West Subbasin totaled approximately 5,017 acres and represented 31 percent of the subbasin. Of this pre-development total, we estimate that 4,959 acres (30 percent of subbasin) were wetlands and 58 acres (less than one percent of subbasin) were natural deepwater lakes. We estimate that approximately 1,527 acres, or nine percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Thirty-one percent of the original 4,959 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 427 acres of wetlands in the Lower White West Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 28 percent of all existing or potential wetlands (1,527 acres) and nine percent of all historic wetlands (4,959 acres). Seventy percent (1,067 acres) of the 1,527 acres of current or potential wetlands have evidence of hydrologic alteration, while 62 percent (942 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1,100 acres (72 percent) of the 1,527 current or potential wetland acres in the Lower White West Subbasin are considered altered.

Of the 1,527 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Lower White West Subbasin include 723 acres of depressional wetlands (47 percent) and 749 acres of riverine wetlands (49 percent). Anadromous fish are estimated to have access to 33 percent (519 acres) of the 1,585 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on much of the 67-meter wide riparian corridors in the Lower White River West basin, but there are still significant forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Forty-nine percent of the riparian zone remains forested, or 1,390 acres of 2,862 total acres, though road crossings have disconnected many of these areas. Most of the riparian forest lies on slopes along the valley walls. Of the non-forested riparian corridor, 38 areas comprising 313 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The flows of the White River formerly split, with a portion flowing north to Elliot Bay via the Green River. In 1906, a natural channel avulsion cut off this channel and the entire White River flowed down what was previously known as the Stuck River into the Puyallup River. This channel modification was reinforced by levees and other floodworks by 1916. In addition, the Mud Mountain Dam, located at RM 29.6, reduces peak flow on the White to 20,000 cfs, and numerous levees have changed the flood inundation areas and eliminated much of the White River's original floodplain.

The Lower White West Subbasin is located closer to major population centers in the Tacoma vicinity and is more heavily developed than the Lower White East Subbasin. The diversion of the White River down the former Stuck River channel has resulted in considerable flooding problems, necessitating extensive levee construction, channelization and meander straightening. These activities have severely impacted floodplain connectivity in this subbasin (USACE, 2002). Of the 8,162 acres of original floodplain, only 308 remain, representing a loss of 96 percent of the historic floodplain.

Water quality

The Lower White River West subarea has a diverse set of land covers, including heavy industry, agriculture, commercial, and residential land covers. The subbasin includes the municipalities of Algona, Pacific, Edgewood and a portion of Sumner. Forest cover is generally very sparse in the subbasin and relegated mostly to the drift plain plateau located to the west of the White River valley. The overall lack of forest cover results in relatively high runoff rates and pollutant loads.

Fish resources

Chinook, coho, steelhead, pink, sockeye, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. All species utilize the mainstem White, primarily as a migration corridor for adults returning to spawning areas further upstream and for juveniles traveling to the ocean.

Chinook are found primarily in the mainstem White, but also in the valley floor reaches of larger tributaries (Strawberry Creek, Bowman Creek, unnamed tributaries at river mile 1.3 and river mile 4.1). Coho, cutthroat and steelhead will utilize the same tributaries, though will generally penetrate farther upstream. In addition to the mainstem, pink salmon will utilize Strawberry Creek.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Lower White River and its tributaries in the Lower White West Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Lower White West Subbasin is predominantly in a "not properly functioning" condition for the delivery of water. Exceptions include four DAUs in the northeast part of the subbasin and one DAU in the southwest that are considered to be in an “at risk” condition. (Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Lower White River and its tributaries in the Lower White West Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the Lower White West Subbasin is primarily in an “at risk” condition for the delivery of sediment. Exceptions include three DAUs in the northeast part of the subbasin in which two DAUs are considered “not properly functioning” and one considered to be “properly functioning” (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Lower White River and its tributaries in the Lower White West Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Lower White West Subbasin is primarily in a “not properly functioning” condition for the delivery and routing of large wood. Exceptions include a cluster of DAUs in the northeast part of the subbasin having two “properly functioning” DAUs and three DAUs considered to be “at risk, along with single DAUs in the southeast and northwest corners of the subbasin considered to be “at risk” (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Lower White River and its tributaries in the Lower White West Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Lower White West Subbasin is predominantly in a “not properly functioning” condition for aquatic integrity. Exceptions include a group of five DAUs in the northeast part of the subbasin and two DAUs on the subbasins western boundary considered to be “at risk” (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 26 percent (4,199 total forested acres) of the Lower White River West Subbasin. Most of the remaining forest lies along the slopes of the west and east valley walls, with a larger patch structurally connected to the concentrated main patch of the Lower White River East Subbasin, and a few patches in the valley (Figure 58, “Upland Forest Cover”). Due to increasing urban, commercial, and agricultural land use in the valley, the widely dispersed forest cover in the Lower White River West

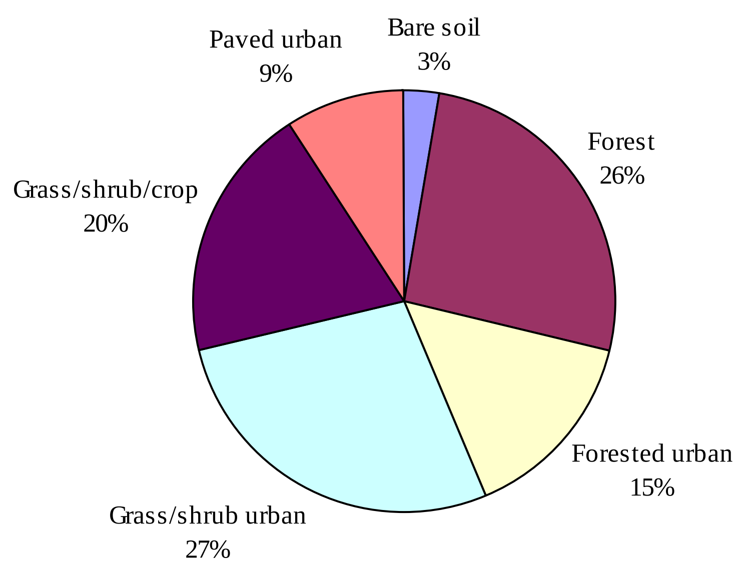
Subbasin is considered “not properly functioning” for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Mid Puyallup North Subbasin?

The Mid-Puyallup North Subbasin includes all areas draining to the Puyallup River from the confluence with the Carbon River (RM 19.9) near Orting downstream to a point approximately 500 feet upstream of the I-5 bridge (RM 2.5), except for areas draining to the White River, Fennel Creek, Clark Creek, the upper portion of lower Wapato Creek, and the upper portion of Clear Creek (see Figure 32, Mid-Puyallup North Subbasin). Total subbasin area is 17,080 acres (26.7 sq. mi.). Significant tributaries include the White River, the Carbon River, Clear Creek, Clark Creek, Wapato Creek, Fennel Creek, and Canyon Falls Creek.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin; oak woodland/prairie occurred on well-drained upland outwash deposits in the southwest portion of the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.



Land cover data from 1998 Landsat images.

Figure 31. Current Land Use in the Mid Puyallup North Subbasin.

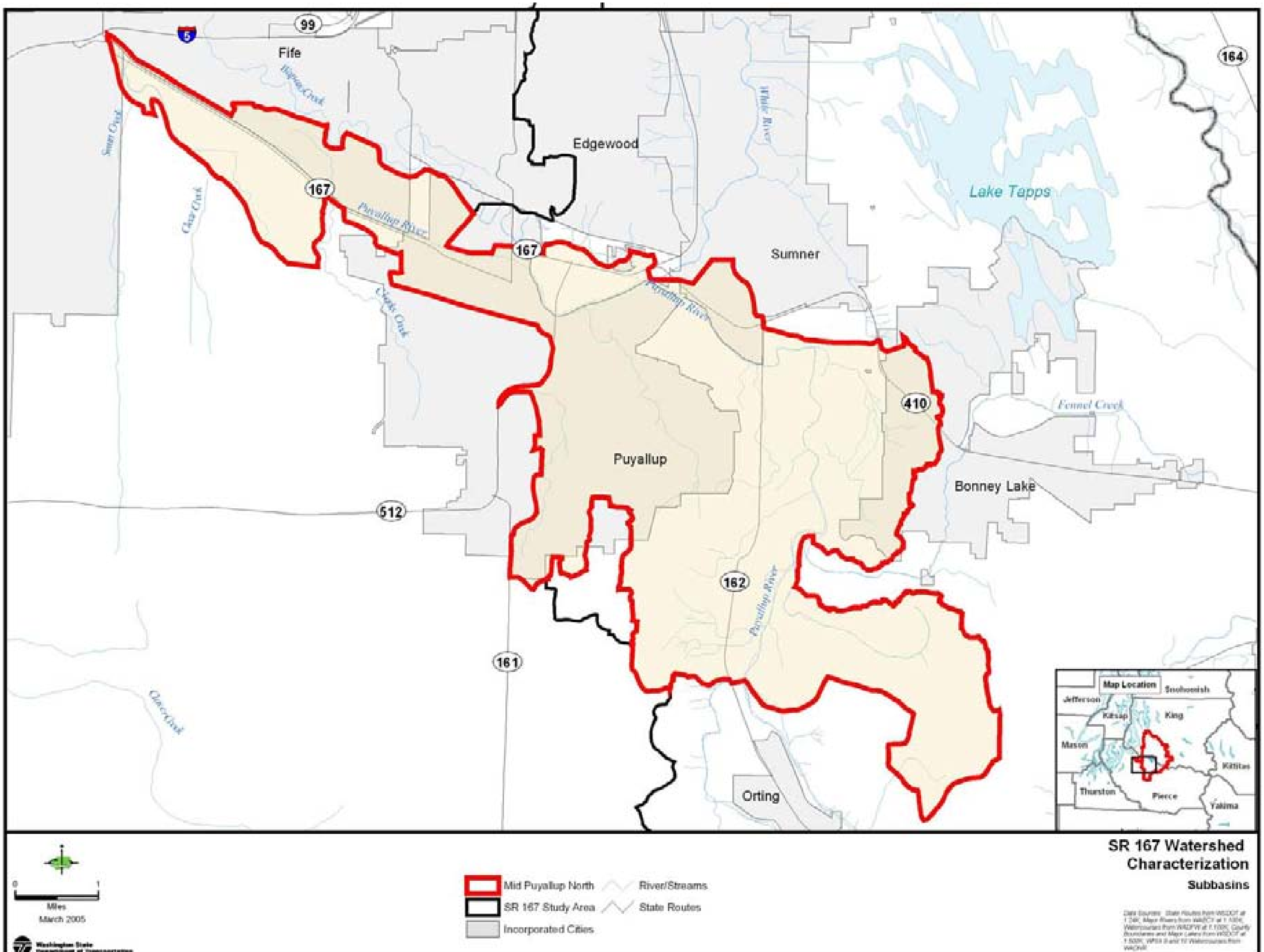


Figure 32. Mid Puyallup North Subbasin.

Current conditions

Based on 1998 LANDSAT imagery, the Mid-Puyallup North Subbasin is split evenly between urban (51 percent) and non-urban (49 percent) land covers (see Figure 31, Current Land Use in the Mid Puyallup North Subbasin. The most intense commercial and industrial land uses occur within the cities of Puyallup and Sumner. The valley floors of the Puyallup and White Rivers outside of these cities consist primarily of agricultural and rural residential land use. Moderate- to high-density residential and commercial development occurs in the upland areas. Forested areas are concentrated on hill slopes and in ravines between the upland and valley areas.

Future conditions

Future land use in the Mid Puyallup North Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 39 percent to 46 percent.

Hydrogeology and groundwater recharge

Approximately 60 percent of the subbasin area lies on the Puyallup valley floor, which consists of alluvium and mudflow deposits laid down since the last glacial advance. Upland areas consist of till and thick outwash deposits. Soils established on till and mudflows convey storm flow rapidly as surface drainage, forming small creeks that cut steep ravines as they descend to the valley floor. Some surface runoff infiltrates into outwash deposits, where it may be conveyed to seepage zones lining the valley margins; these seepage zones serve as an important water source for wetlands and small tributaries found on the valley floor. Outwash deposits cover 31 percent of the subbasin, primarily in upland areas to the east and west of the valley. Approximately 30 percent of these important groundwater recharge areas are now covered by impervious surfaces.

Upland outwash deposits to the west of the valley are included in the Central Pierce County Sole Source Aquifer, and valley floor deposits are included as a part of a Pierce County Critical Aquifer Recharge area.

Runoff and streamflow

The Puyallup River originates on the Tahoma and Puyallup Glaciers on the west flank of Mt. Rainier and flows through the Cascade range for approximately 28 miles to the study area boundary. Total watershed area at the long-term USGS stream gage located within the subbasin (12101500 – Puyallup River at Puyallup) is 948 square miles. Mean annual discharge at this gage is 3,323 cfs. An instream flow requirement was established in 1980 to provide a minimum of between 1,000 and 2,000 cfs (depending on time of year) at the gage; these flows were not met an average of 35 days per year between 1980 and 1993. Between 1973 and 1993, data from three USGS Puyallup River basin gages show that low flows have dropped, despite above-average precipitation and closure of some streams to new water rights; this decline is attributed to increased demand for groundwater from exempt (< 5000 gpd) wells and increases in impervious surfaces which cause reductions in runoff storage.

A system of levees constructed over the last century extends the length of the Puyallup River within the study area, and has greatly reduced the frequency and extent of flooding within the subbasin for floods up to about the 35-year event. Extensive aggradation within the river is evident, and may result in further reduction in channel conveyance over time. On the valley floor, most tributaries have been ditched and straightened to accommodate agricultural activities.

Increased urbanization is occurring within the subbasin, both on the valley floor and on the upland drift plain. TIA is estimated to be approximately 39 percent based on 1998 Landsat imagery, and is likely to be significantly greater based on the extent of development that is currently occurring.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Mid Puyallup North Subbasin totaled approximately 2,800 acres and represented 16 percent of the subbasin. Of this pre-development total, we estimate that all were wetlands. No natural deepwater lakes were noted. We estimate that approximately 1,119 acres, or seven percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Forty percent of the original 2,800 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 309 acres of wetlands in the Mid Puyallup North Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 28 percent of all existing or potential wetlands (1,119 acres) and 11 percent of all historic wetlands (2,800 acres). Sixty-five percent (732 acres) of the 1,119 acres of current or potential wetlands have evidence of hydrologic alteration, while 58 percent (644 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 810 acres (72 percent) of the 1,119 current or potential wetland acres in the Mid Puyallup North Subbasin are considered altered.

Of the 1,119 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Mid Puyallup North Subbasin include 805 acres of depressional wetlands (72 percent) and 314 acres of riverine wetlands (28 percent). Anadromous fish are estimated to have access to 25 percent (279 acres) of the 1,119 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on much of the 67-meter wide riparian corridors in the Mid Puyallup River North basin, but there are still significant forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Forty-eight percent of the riparian zone remains forested, or 1,314 acres of 2,714 total acres, though road crossings have disconnected many of these areas. Most of the riparian forest lies on slopes and canyons along the valley walls. Of the non-forested riparian corridor, 64 areas comprising 566 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The Mud Mountain Dam, completed in 1943, controls flows on the Puyallup River, and extensive levee systems have greatly reduced flooding on the Puyallup River. Significant flooding still occurs in the vicinity of Orting (Federal Emergency Management Agency, 1987).

Of the 9,601 acres of original floodplain in the Mid Puyallup River North Subbasin, only 3,438 acres remain, a reduction of 64 percent. Generally this subbasin is more heavily developed than the Mid Puyallup River South. The levee systems tend to be more robust, however bed aggradation is also a notable geomorphic characteristic of many Mid Puyallup North reaches. Recent studies of the Lower Puyallup indicate a loss of freeboard on the levee system indicative of ongoing reach, or subbasin scale bed aggradation problems (Federal Emergency Management Agency, 2004).

Water quality

The Middle Puyallup River North Subbasin centers around the confluence of the Lower White and Puyallup Rivers. It is fully within the urban growth boundary and is currently undergoing a significant amount of urbanization and conversion of former farmland to residential neighborhoods. The two DAUs that displayed properly functioning conditions for water quality were both located on parts of the Bonney Lake plateau area which are currently forested but is expected to be developed within the next decade.

Fish resources

Chinook, coho, steelhead, pink, sockeye, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. All species utilize the mainstem Puyallup, primarily as a migration corridor for adults returning to spawning areas further upstream and for juveniles traveling to the ocean.

Chinook are found primarily in the mainstem Puyallup, but also in the valley floor reaches of larger tributaries (Clark Creek, Canyon Falls Creek, unnamed tributaries at river mile 13 and river mile 14.9). Coho, cutthroat and steelhead will utilize the same tributaries, though will generally penetrate farther upstream. In addition to the mainstem, pink salmon will utilize lower Clark Creek.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Puyallup River and its tributaries in the Mid Puyallup North Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the entire Mid Puyallup North Subbasin is in a “not properly functioning” condition for the delivery of water (Figure 48, “Condition of the

Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Puyallup River and its tributaries in the Mid Puyallup North Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the Mid Puyallup North Subbasin is primarily in an "at risk" condition for the delivery of sediment. Exceptions include the two DAUs is the far southeastern part of the subbasin that are considered to be in a "properly functioning" condition (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Puyallup River and its tributaries in the Mid Puyallup North Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Mid Puyallup North Subbasin is a mix of DAUs in either an "at risk" or a "not properly functioning" condition for the delivery and routing of large wood (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the Puyallup River and its tributaries in the Mid Puyallup North Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Mid Puyallup North Subbasin is predominantly in a "not properly functioning" condition for aquatic integrity. Exceptions include the two DAUs in the southeastern part of the subbasin considered to be in an "at risk" condition (Figure 56, "Condition Map for Aquatic Integrity," and Figure 57, "Overall Condition map for Aquatic Integrity").

Upland forest cover

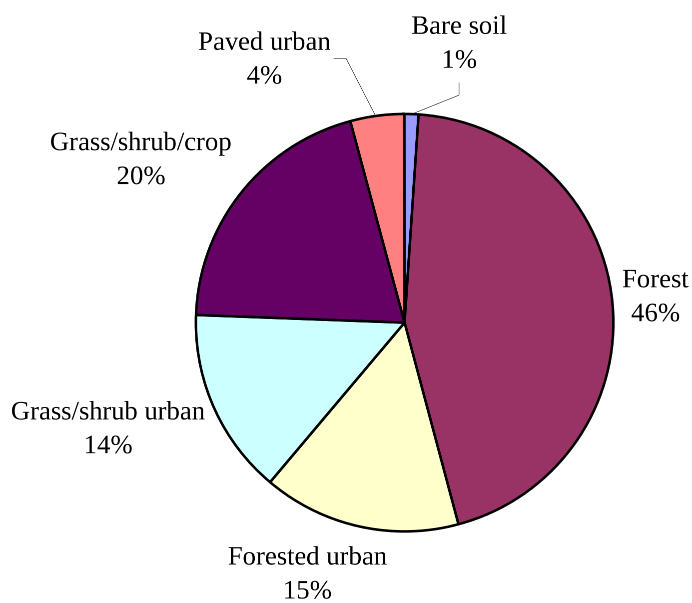
Forest covers 26 percent (4,410 total forested acres) of the Mid Puyallup River North Subbasin. Most of the remaining forest lies along the slopes of the east and west sides of the valley, connected to a larger patch network in Mid Puyallup River South Subbasin and one along Canyon Falls Creek that connects to the Fennel Creek, Lower Carbon River, and South Prairie Creek Subbasins (Figure 58, "Upland Forest Cover"). Due to the otherwise widely dispersed forest cover in the valley of the Mid Puyallup River North Subbasin, it is considered "not properly functioning" for upland forest cover and has a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, "Final Condition Map for Forest Density Areas").

What conditions did we find in the Mid Puyallup South Subbasin?

The Mid-Puyallup South Subbasin includes all areas draining to the Puyallup River from the confluence with the Carbon River (RM 19.9) near Orting upstream to a point approximately 350 ft downstream of the Orville Road bridge near the confluence with Fiske Creek (RM 26.5). Total subbasin area is 11,052 acres (17.3 sq. mi.). There are no significant tributaries in the subbasin (see Figure 34, Mid-Puyallup South Subbasin).

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin; oak woodland/prairie occurred on well-drained upland outwash deposits (see Figure 36, Mid Puyallup South Subbasin). Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.



Land cover data from 1998 Landsat images.

Figure 33. Current Land Use in the Mid Puyallup South Subbasin.

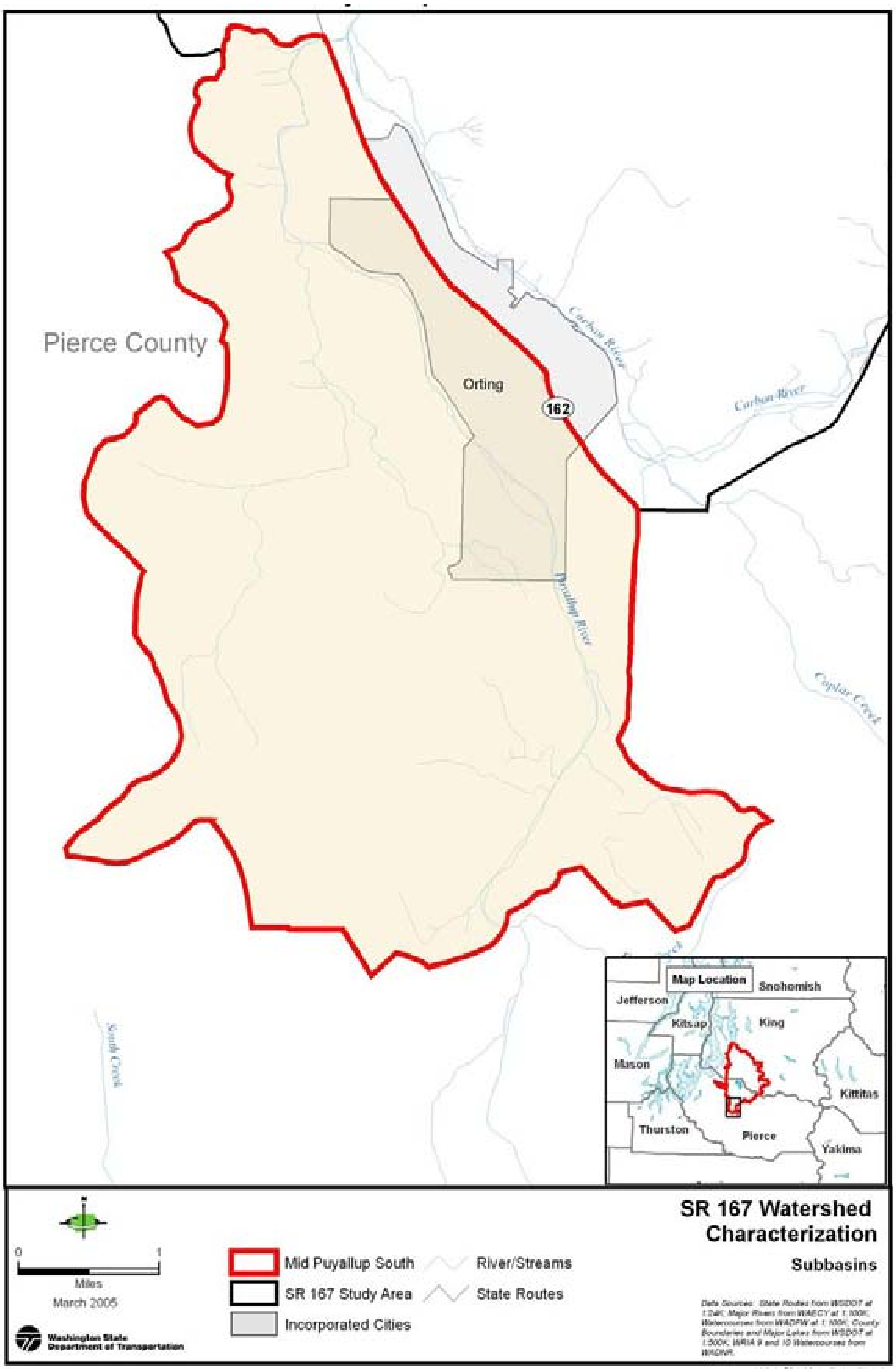


Figure 34. Mid Puyallup South Subbasin.

Current conditions

Based on 1998 LANDSAT imagery, the Mid-Puyallup South subbasin is comprised primarily of forest land cover (46 percent); urban land covers account for 33 percent of the subbasin (see Figure 33, Current Land Use in the Mid Puyallup South Subbasin). Most of the higher-density development occurs in and around the city of Orting. The valley floor of the Puyallup River outside of Orting has primarily agricultural and rural residential land use. Various types of residential land use (low-, moderate-, and high-density) occur in the upland areas. Forested areas are concentrated on hill slopes and in ravines between the upland and valley areas, and in undeveloped portions of the upland areas.

Future conditions

Future land use in the Mid Puyallup South Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 24 percent to 28 percent.

Hydrogeology and groundwater recharge

Approximately 40 percent of the subbasin area lies on the Puyallup valley floor, which consists of alluvium and mudflow deposits laid down since the last glacial advance. Upland areas consist of till and thick outwash deposits. Soils established on till and mudflows convey storm flow rapidly as surface drainage, forming small creeks that cut steep ravines as they descend to the valley floor. Some surface runoff infiltrates into outwash deposits, where it may be conveyed to seepage zones lining the valley margins; these seepage zones serve as an important water source for wetlands and small tributaries found on the valley floor.

Outwash deposits cover 42 percent of the subbasin, primarily in upland areas to the west of the valley. Approximately 20 percent of these important groundwater recharge areas are now covered by impervious surfaces.

Upland outwash deposits to the west of the valley are included in the Central Pierce County Sole Source Aquifer, and valley floor deposits are included as a part of a Pierce County Critical Aquifer Recharge area.

Runoff and streamflow

The Puyallup River originates on the Tahoma and Puyallup Glaciers on the west flank of Mt. Rainier and flows through the Cascade range for approximately 28 miles to the study area boundary. Total watershed area at the USGS stream gage near the study area boundary (12093500 – Puyallup River near Orting) is 171 square miles. Mean annual discharge at this gage is 714 cfs. Up to 400 cfs is diverted at river mile 41.8 for the Puget Sound Energy Electron hydro project. Diverted flow is returned to the river approximately two miles upstream from the study area boundary.

A system of levees constructed over the last century extends the length of the Puyallup River within the study area, and has greatly reduced the frequency and extent of flooding within the subbasin for floods up to about the 35-year event. Extensive aggradation within the river is evident, and may result in further reduction in channel conveyance over time. A setback levee project was completed in 1998 between river miles 23.8 and 24.8 which increased in the active channel width from about 150 feet to between 800 and 1,300 feet. On the valley floor, most tributaries have been ditched and straightened to accommodate agricultural activities.

Increased urbanization is occurring within the subbasin, both on the valley floor and on the upland drift plain. TIA is estimated to be approximately 24 percent based on 1998 Landsat imagery, and is likely to be significantly greater based on the extent of development that is currently occurring.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Mid Puyallup South Subbasin totaled approximately 1,246 acres and represented 11 percent of the subbasin. Of this pre-development total, we estimate that 1,238 acres (11 percent of subbasin) were wetlands and seven acres (less than one percent of subbasin) were natural deepwater lakes. We estimate that approximately 1,102 acres, or 10 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Eighty-nine percent of the original 1,238 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 467 acres of wetlands in the Mid Puyallup South Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 42 percent of all existing or potential wetlands (1,102 acres) and 38 percent of all historic wetlands (1,238 acres). Fifty-seven percent (624 acres) of the 1,102 acres of current or potential wetlands have evidence of hydrologic alteration, while 43 percent (473 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 635 acres (58 percent) of the 1,102 current or potential wetland acres in the Mid Puyallup South Subbasin are considered altered.

Of the 1,102 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Mid Puyallup South Subbasin include 482 acres of depressional wetlands (44 percent) and 616 acres of riverine wetlands (56 percent). Anadromous fish are estimated to have access to 43 percent (474 acres) of the 1,109 acres of natural deepwater lakes and current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the Mid Puyallup River South basin, but there are still significant forested areas (Figure 47, “Condition of Riparian Systems by Subbasin”). Of the 1,451 total acres, 69 percent (999 acres) remain forested, though road crossings have disconnected some of these areas. Of the non-forested riparian corridor, 21 areas comprising 163 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

The Mud Mountain Dam, completed in 1943, controls flows on the Puyallup River, and extensive levee systems have greatly reduced flooding on the Puyallup River. Significant flooding still occurs in the vicinity of Orting (Federal Emergency Management Agency, 1987).

The Puyallup River south of Orting has a slope of approximately 45 feet per mile, whereas the valley slope from Orting downstream is decreased to 25 feet per mile. This decrease in channel slope reduces the velocity and bedload transport capacity of the river. Because of this, sediment transported from the steep upstream valley is deposited in the reach at and below Orting. Channel aggradation within this reach has been estimated by FEMA to be 5 feet higher than adjacent portions of the floodplain outside the channel levees (Federal Emergency Management Agency, 1987). Regardless of this ongoing flood threat, development pressure in this part of the Puyallup is still considerable.

Of the 3,592 acres of original floodplain in the Mid Puyallup South Subbasin, only 2,014 acres remain, a reduction of 44 percent.

Water quality

The Middle Puyallup River South subbasin accounts for the lowermost reaches of the Puyallup River, just prior to its confluence with the Carbon River in northern Pierce County. The subbasin lies between the Bonney Lake plateau on the northeast and the Puyallup plateau to the southwest. This subbasin is in transition, being converted from forest land cover and farmland to mostly residential land uses. However, significant forest patches still exist. As a consequence, the subbasin displays significant variations in both water quality characteristics and ecologic function. Currently the DAUs that have been most impacted by water quality limitations are located adjacent to the river and SR-165, the main thoroughfare through the subbasin. Future land development on the Puyallup plateau may negatively influence water quality trends in the subbasin.

Fish resources

Chinook, coho, steelhead, pink, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. All species utilize the mainstem Puyallup, primarily as a migration corridor for adults returning to spawning areas further upstream and for juveniles traveling to the ocean.

Chinook are found primarily in the mainstem Puyallup, but also in the valley floor reaches of an unnamed tributary at RM 20.2. Coho, cutthroat, steelhead and pink salmon also utilize this tributary

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the Puyallup River and its tributaries in the Mid Puyallup South Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the Mid Puyallup South Subbasin is predominantly in an “at risk condition for the delivery of water. Exceptions include two DAUs associated with the town of Orting that are in a “not properly functioning” condition (Figure 48, “Condition of the Movement of Water,” and Figure 49, “Overall Condition of the Movement of Water”).

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the Puyallup River and its tributaries in the Mid Puyallup South Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire Mid Puyallup South Subbasin is in an “at risk” condition for the delivery of sediment (Figure 52, “Condition of the Movement of Sediment,” and Figure 53, “Overall Condition of the Movement of Sediment”).

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the Puyallup River and its tributaries in the Mid Puyallup South Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the Mid Puyallup South Subbasin is primarily in an “at risk” condition for the delivery and routing of large wood. The lone exception is a single “not properly functioning” DAU in the center of the subbasin (Figure 55, “Condition of the Movement of Large Wood,” and Figure 56, “Overall Condition of the Movement of Large Wood”).

Aquatic integrity

The effects of human land use on aquatic integrity in the Puyallup River and its tributaries in the Mid Puyallup South Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the Mid Puyallup South Subbasin is predominantly in an “at risk” condition for aquatic integrity. Exceptions include the two northernmost DAUs considered to be in a “not properly functioning” condition (Figure 56, “Condition Map for Aquatic Integrity,” and Figure 57, “Overall Condition map for Aquatic Integrity”).

Upland forest cover

Forest covers 45 percent (4,924 total forested acres) of the Mid Puyallup River South Subbasin. The remaining forest is concentrated in an aggregate of patches on the upslope west side of the valley, connected to a tail of patches in the Mid Puyallup River North Subbasin (Figure 58, “Upland Forest Cover”). The valley’s forest patches remain widely dispersed, giving the Mid Puyallup River South Subbasin an “at risk” rating for upland forest cover with a median probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

What conditions did we find in the Potholes Subbasin?

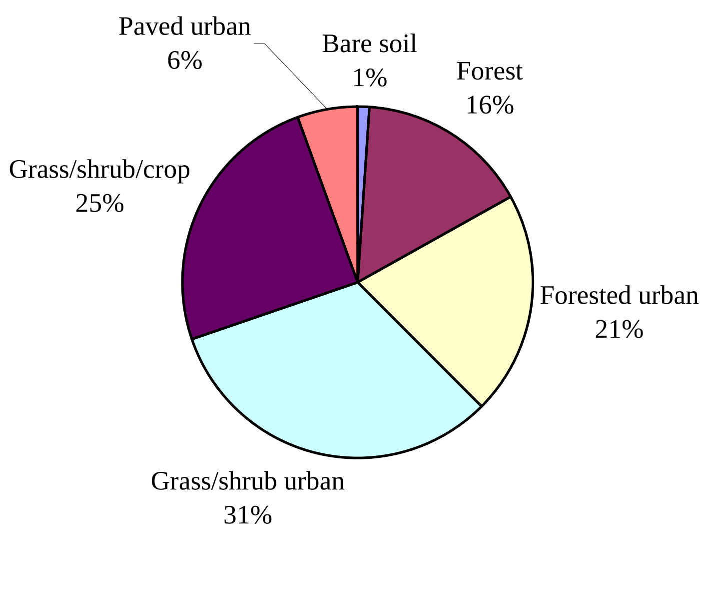
The Potholes Subbasin includes two internally draining (no surface outlet) areas located on the drift plain immediately to the north and south of the mid-Puyallup North subbasin (see Figure 36, Potholes Subbasin). Surface drainage presumably infiltrates to groundwater, where it emerges on or at the toe of the Puyallup and White River valley walls as seeps, springs, and small creeks. This subbasin also includes a portion of Wapato Creek near its confluence with the Puyallup River. Total subbasin area is 3,343 acres (5.22 sq. mi.). There are no significant tributaries.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Based on 1998 LANDSAT imagery, the Potholes Subbasin are comprised primarily of urban (58 percent) land covers, followed by grass/shrub/crop (25 percent) and forest (16 percent) land covers (see Figure 35, Current Land Use in the Potholes Subbasin).



Land cover data from 1998 Landsat images.

Figure 35. Current Land Use in the Potholes Subbasin.

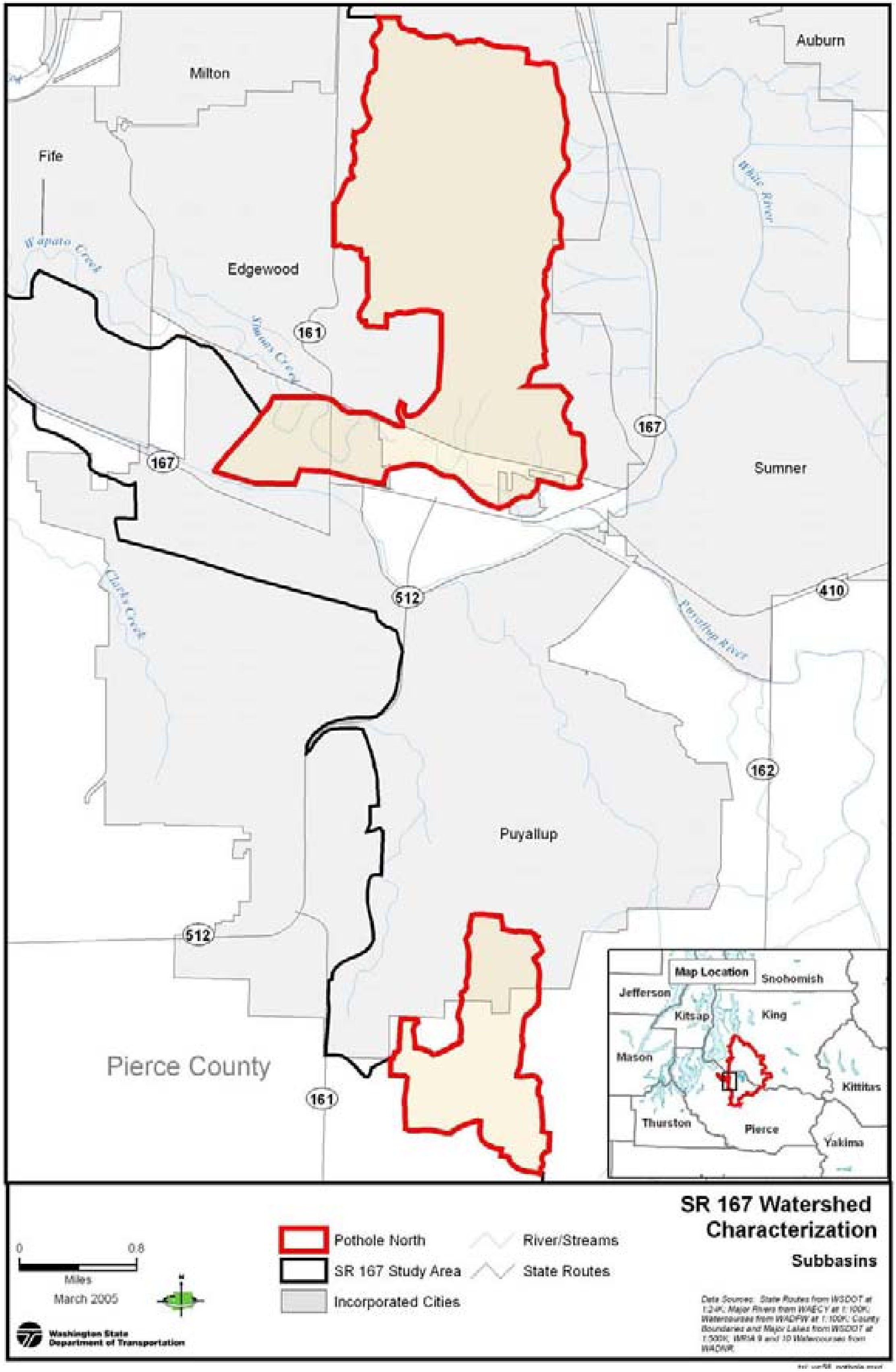


Figure 36. Potholes Subbasin.

Future conditions

Future land use in the Potholes Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 40 percent to 46 percent.

Hydrogeology and groundwater recharge

The Potholes Subbasin is underlain by till and thick outwash deposits, except for Wapato Creek, which flows through coarse alluvial deposits on the Puyallup valley floor. Soils established on till convey storm flow rapidly as surface drainage. Some of this surface flow accumulates in several kettle ponds scattered across the upland portion of the subbasin, where it may evaporate or infiltrate into the local groundwater system. Some surface runoff infiltrates into outwash deposits, where it may be conveyed to seepage zones lining the valley margins. These seepage zones serve as an important water source for wetlands and small tributaries found on the valley floor. Outwash deposits cover 20 percent of the subbasin, primarily in upland area to the south of the valley. Approximately 44 percent of these important groundwater recharge areas are now covered by impervious surfaces.

Upland outwash deposits to the south and west of the valley are included in the Central Pierce County Sole Source Aquifer, and valley floor deposits are included as a part of a Pierce County Critical Aquifer Recharge area.

Runoff and streamflow

There are no USGS gages in the subbasin.

With the exception of three minor creeks draining the valley wall north of Wapato Creek, all surface flow in the upland portions of the Potholes Subbasin appear to either evaporate or infiltrate to the local groundwater system. The subbasin includes the lowermost 1.5 square miles of the Wapato creek watershed (total watershed area = 12 sq. mi.). Flow is diverted to the Puyallup River upstream of the subbasin to reduce flooding. This reach runs dry in the summer due to irrigation withdrawals and infiltration into permeable alluvium.

TIA is estimated to be approximately 40 percent in 1998 Landsat imagery.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the Potholes Subbasin totaled approximately 253 acres and represented nine percent of the subbasin. Of this pre-development total, we estimate that 244 acres (7.5 percent of subbasin) were wetlands and nine acres (less than one percent of subbasin) were natural deepwater lakes. We estimate that approximately 156 acres, or five percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Sixty-three percent of the original 244 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 87 acres of wetlands in the Potholes Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 56 percent of all existing or potential wetlands (156 acres) and 36 percent of all historic wetlands (244 acres). Thirty-two percent (50 acres) of the 156 acres of current or potential wetlands have evidence of hydrologic alteration, while 38 percent (59 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 69 acres (44 percent) of the 156 current or potential wetland acres in the subbasin are considered altered.

Of the 156 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the Potholes Subbasin include 140 acres of depressional wetlands (90 percent) and 14 acres of riverine wetlands (nine percent). Based on the landscape position of fish-bearing streams in relation to the 165 acres of natural deepwater lakes and current or potential wetlands in this subbasin, we estimate that no existing/potential lake or wetland sites are accessible to anadromous fish.

Riparian condition

Urban development has encroached on most of the 67-meter wide riparian corridors in the Potholes subbasin, but there are still some forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Of the 230 total acres, 27 percent, or 62 acres, of the riparian zone remains forested, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, five areas comprising 40 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of any considerable size were evaluated in the Potholes Subbasin. The total original floodplain acreage was only 512 acres. Of this, only one-tenth of an acre remains today – a reduction of nearly 100 percent.

Potential restoration sites were evaluated in terms of potential habitat, wetland, and/or riparian functions. (see sections on wetlands and riparian).

Water quality

The Pothole subbasin is typified by either established or developing residential neighborhoods and glacial drift soils. As a result, all of the contributing DAUs exhibited either degraded or degrading conditions for water quality. Continued urbanization, regardless of stormwater management strategies, is likely to continue this trend.

Fish resources

There is no fish utilization of the Potholes Subbasin.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the streams in the Potholes Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the entire subbasin is in a "not properly functioning" condition for the delivery of water (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the streams in the Potholes Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire subbasin is in an "at risk" condition for the delivery of sediment (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the streams in the Potholes Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the entire subbasin is in a "not properly functioning" condition for the delivery and routing of large wood (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the streams in the Potholes Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the entire subbasin is in a "not properly functioning" condition for aquatic integrity (Figure 56, "Condition Map for Aquatic Integrity," and Figure 57, "Overall Condition map for Aquatic Integrity").

Upland forest cover

Forest covers only 15 percent (498 total forested acres) of the relatively small Potholes Subbasin (Figure 58, "Upland Forest Cover"). The forest is widely dispersed and the subbasin is considered "not properly functioning" for upland forest cover with a very low probability of supporting habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, "Final Condition Map for Forest Density Areas").

What conditions did we find in the South Prairie Creek Subbasin?

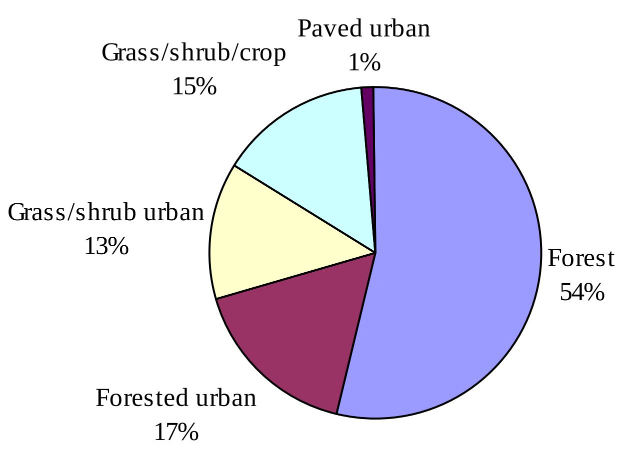
The South Prairie Creek Subbasin includes all areas draining to South Prairie Creek from the base of the Cascade foothills (RM 10.5), except for the portion of Wilkeson Creek outside the study area (see Figure 38, South Prairie Creek Subbasin). Total subbasin area is 12,678 acres (19.8 sq. mi.). Significant tributaries within the subbasin include Wilkeson Creek and the Spiketon (agricultural) ditch.

Pre-development land cover

Prior to European settlement, coniferous forest covered most of the glacial drift plain, hill slopes, and confined stream valleys in the subbasin. Areas subject to relatively frequent disturbance, such as floodplains and unstable slopes, were covered by deciduous forest; less frequently disturbed terraces were covered by mixed deciduous-conifer forest.

Current conditions

Based on 1998 LANDSAT imagery, the South Prairie Creek Subbasin is comprised primarily of forest land cover (54 percent); urban land covers account for 31 percent of the subbasin area (see Figure 37, Current Land Use in the South Prairie Creek Subbasin). The valley floor of South Prairie Creek has primarily agricultural and rural residential land use. The upland area has a mix of land uses, including forest, agriculture, rural residential, and moderate- and high-density residential. Development of a proposed master planned community is expected to convert much of the remaining forested upland area to moderate- and high-density residential and commercial land use.



Land cover data from 1998 Landsat images.

Figure 37. Current Land Use in the South Prairie Creek Subbasin.

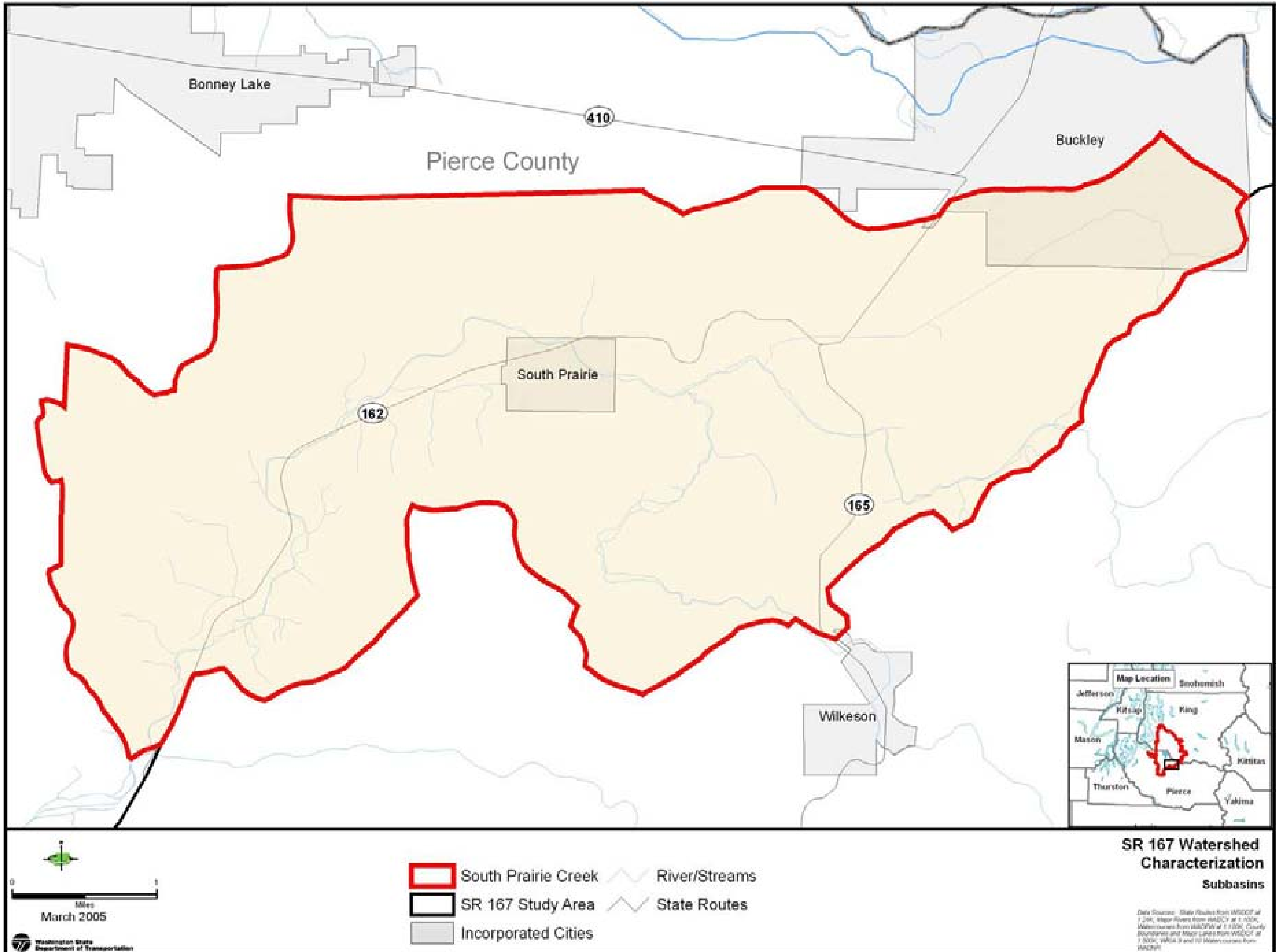


Figure 38. South Prairie Creek Subbasin.

Future conditions

Future land use in the South Prairie Creek Subbasin is predicted to reflect a moderate increase in residential and commercial development, increasing the TIA from 20 percent to 22 percent.

Hydrogeology and groundwater recharge

Approximately 15 percent of the subbasin area lies on the valley floor, which consists of alluvium and mudflow deposits laid down since the last glacial advance. Upland areas consist of till and thick outwash deposits, which are mantled along the northern portion of the subbasin by mudflow deposits. Soils established on till and mudflows convey storm flow rapidly as surface drainage, forming small creeks that cut steep ravines as they descend to the valley floor. Some surface runoff infiltrates into outwash deposits, where it may be conveyed to seepage zones lining the valley margins; these seepage zones serve as an important water source for wetlands and small tributaries found on the valley floor. Outwash deposits cover 39 percent of the subbasin, primarily in upland areas to the north and south of the valley. Approximately 23 percent of these important groundwater recharge areas are now covered by impervious surfaces.

Valley floor deposits are included as a part of a Pierce County Critical Aquifer Recharge area.

Runoff and streamflow

South Prairie Creek originates in the Cascade range north of Mount Rainier and flows northward for approximately 12 miles to the study area boundary. Human impacts on the creek over this distance are relatively minor and are associated with forest practice activities.

Total watershed area at the long-term USGS stream gage located within the study area at river mile 5.9 (12094400 – South Prairie Creek at South Prairie) is 24.5 square miles. Mean annual discharge at this gage is 234 cfs.

Most of the creek within the study area is either incised in drift and mudflow deposits or confined by levees, roadbeds, or railroad grades. In the lowermost five miles of the creek, the levees have not been actively maintained for at least the last 20 years and the stream is slowly recapturing portions of its historical floodplain.

Increased urbanization is occurring within the subbasin, both on the valley floor and on the upland drift plain. TIA is estimated to be approximately 20 percent.

Wetlands

Prior to human alteration, wetlands and deepwater lakes in the South Prairie Creek Subbasin totaled approximately 2,955 acres and represented 23 percent of the subbasin. Of this pre-development total, we estimate that all 2,955 acres were wetlands. No natural deepwater lakes were noted in this subbasin. We estimate that approximately 1,606 acres, or 13 percent of the subbasin, are currently wetlands or highly degraded/destroyed wetlands with some restoration potential. Fifty-four percent of the original 2,955 pre-development wetland acres remain as existing or potential wetlands.

Based on photo interpretation, we estimate that 343 acres of wetlands in the South Prairie Creek Subbasin are considered properly functioning (having little or no hydrologic or vegetative alteration). These properly functioning wetlands represent 21 percent of all existing or potential wetlands (1,606 acres) and 12 percent of all historic wetlands (2955 acres). Seventy-five percent (1,209 acres) of the 1,606 acres of current or potential wetlands have evidence of hydrologic alteration, while 78 percent (1,260 acres) have some level of vegetative alteration. When both hydrologic and vegetative alterations are considered together, 1,262 acres (79 percent) of the 1,606 current or potential wetland acres in the South Prairie Creek Subbasin are considered altered.

Of the 1,606 acres of current or potential wetland acres, dominant hydrogeomorphic wetland classes in the South Prairie Creek Subbasin include 1,296 acres of depressional wetlands (81 percent) and 299 acres of riverine wetlands (19 percent). Anadromous fish are estimated to have access to 50 percent (798 acres) of the 1,606 acres of current or potential wetlands in this subbasin.

Riparian condition

Urban development has encroached on some of the 67-meter wide riparian corridors in the South Prairie Creek basin, but there are still significant forested areas (Figure 47, "Condition of Riparian Systems by Subbasin"). Seventy-four percent of the riparian zone remains forested, or 1,158 acres of 1,573 total acres, though road crossings have disconnected many of these areas. Of the non-forested riparian corridor, 11 areas comprising 99 acres could potentially be considered riparian mitigation sites.

Floodplain Condition

No potential floodplain restoration areas of considerable size were evaluated in the South Prairie Creek Subbasin for this study. Potential restoration sites in floodplain areas for this sub-basin were evaluated in terms of potential aquatic habitat, wetland, and/or riparian functions (see sections on wetlands and riparian).

Water quality

The South Prairie Creek is regarded as the best salmonid stream in WRIA 10, and water quality conditions in this subbasin tend to support this view. Land cover is mostly forested or agricultural. In the WRIA 10 portions of the SR-167 study area, the subbasin displayed the best overall water quality conditions. SR-162 and SR-165, both low traffic volume roads, contribute runoff volumes and pollutant loads to the South Prairie Creek Subbasin.

Fish resources

Chinook, coho, steelhead, pink, bull trout and cutthroat spend one or more parts of their life cycle in this subbasin. All species utilize South Prairie Creek, Wilkeson Creek, and the Spiketon ditch for spawning and/or rearing.

Human alteration to the movement of water

The effects of human land use on the natural delivery of water to the South Prairie Creek and its tributaries in the South Prairie Creek Subbasin were characterized using the following landscape attributes: percent TIA and percent forest land cover at the DAU scale. Results indicate that the South Prairie Creek Subbasin is in an "at risk" condition for the delivery of water, with the exception of one "not properly functioning DAU in the north-central part of the subbasin (Figure 48, "Condition of the Movement of Water," and Figure 49, "Overall Condition of the Movement of Water").

Human alteration to the natural movement of sediment

The effects of human land use on the natural delivery of sediment to the South Prairie Creek and its tributaries in the South Prairie Creek Subbasin were characterized using the following landscape attributes: percent bare soils, road density, and percent unstable slopes at the DAU scale. Results indicate that the entire South Prairie Creek Subbasin is in an "at risk" condition for the delivery of sediment (Figure 52, "Condition of the Movement of Sediment," and Figure 53, "Overall Condition of the Movement of Sediment").

Human alteration to the natural movement of large wood

The effects of human land use on the natural delivery and routing of large wood to the South Prairie Creek and its tributaries in the South Prairie Creek Subbasin were characterized using the following landscape attributes: percent forested riparian and average number of stream crossings per kilometer of stream at the DAU scale. Results indicate that the South Prairie Creek Subbasin is a mix of DAUs with either a "properly functioning" or an "at risk" condition rank for the delivery and routing of large wood (Figure 55, "Condition of the Movement of Large Wood," and Figure 56, "Overall Condition of the Movement of Large Wood").

Aquatic integrity

The effects of human land use on aquatic integrity in the South Prairie Creek and its tributaries in the South Prairie Creek Subbasin were characterized using the following landscape attributes: percent riparian forest, percent TIA, and available B-IBI scores at the DAU scale. Results indicate that the South Prairie Creek Subbasin is in an "at risk" condition for aquatic integrity. The exception is a single DAU in the north central part of the subbasin considered to be in a "not properly functioning" condition (Figure 56, "Condition Map for Aquatic Integrity," and Figure 57, "Overall Condition map for Aquatic Integrity").

Upland forest cover

Forest covers 54 percent (6,782 total forested acres) of the South Prairie Creek Subbasin. The valley portion of the subbasin, along South Prairie Creek, contains most of the forest cover, linking to the larger forested complex included in the Lower Carbon River, Mid Puyallup North, and Fennel Creek subbasins (Figure 58, “Upland Forest Cover”). Due to the otherwise dispersed forest cover in the rest of the subbasin, the South Prairie Creek subbasin is considered “at risk” for upland forest cover and there is a median probability that the subbasin can support habitat connectivity for organisms that rely upon the predevelopment condition of the landscape (Figure 59, “Final Condition Map for Forest Density Areas”).

IV. Conditions of Natural Resources in the Project Area

Why do we look at the resources in the project area?

Understanding the location, extent, and condition of regulated natural resources within the project area is an essential first step to estimating potential natural resource impacts and avoiding and minimizing those impacts to key natural resources. Developing this information early in the project planning phase provides even greater opportunities to develop project alternatives with key natural resources in mind, saving time in getting necessary permits, reducing the need for redesign, and minimizing the high cost of environmental mitigation.

How was the project area established?

We created the estimated project area by visually surveying the existing fence lines and transferring that information to a GIS data layer. Visual surveys were completed of the SR-167 corridor from the SR-512 interchange at the south to the I-405 interchange on the north. Using orthophotos in the field, an approximate location of existing fence lines were drawn on maps. Using digital orthophotos in ArcMap, a GIS data layer was then created and the estimated project area boundary was transferred from field maps to a digital format. Natural resource information is referenced by SR-167 milepost from south to north.

NOTE - The estimated project area is not intended to depict a legal right-of-way boundary for the project area. Rather, it represents an estimated project area for the purpose of displaying the location and extent of natural resources in association with SR-167 infrastructure.

How were natural resource areas identified?

We used wetland polygons and accompanying data to establish a location and extent of wetland resources in the project area. We developed these using photo interpretation and site verification. They are compiled in the potential wetland restoration site dataset. FEMA 100-year floodplain data were used to map existing floodplain polygons. The potential riparian restoration site database was used to identify forested riparian areas. In this dataset, polygons represent that portion of the riparian area that was cleared of trees. From this data, a new shape file was created that identified the forested riparian areas and were used here to map existing forested riparian areas. Outside of the riparian area, the forest land cover dataset was used to identify upland forest patches in or adjacent to the project area. Hydrologic fragmentation data were derived from the wetland and floodplain datasets listed above, along with geology and soils data used to identify groundwater resources, alluvial fans, seepage zones, and recharge areas. All of the restoration site datasets are available as ArcMap shape files.

What resources are in the project area, and in what condition?

In the following sections we provide a brief summary description of the natural resources in and adjacent to the project area. In Chapter V, this information will be used to estimate potential project impacts and facilitate design work to avoid and minimize natural resource impacts. Detailed information on natural resources is presented in Appendix F.

Wetland resources

The SR-167 project area contains a total of 105 wetlands and 27 wetland ditches, swales or detention ponds that were identified within and adjacent to the project area (see Figures 60, 61, and 62, "Existing Aquatic and Fish Resources"). Of the 105 wetlands, 17 have an Ecology Rating of a Category II and 88 have the rating of a Category III (Washington State Department of Ecology, 1993). The majority of wetlands along the project area provide the principal function of nutrient and toxicant removal with the second most prominent principal function being flood flow alteration. Other functions provided to a lesser extent include habitat for amphibians, habitat for wetland mammals and wetland-associated birds, production of organic matter and its export, general habitat suitability and sediment removal.

Floodplain resources

The 300-foot buffer of the project area intersects several floodplain areas (see Figures 60, 61, and 62, "Existing Aquatic and Fish Resources"). It intersects a portion of FEMA floodplain at the confluence of the White and Puyallup Rivers, on the southeast side of the highway at about milepost 6.5 to milepost 7.2. There is also a significant amount of floodplain along the portion of the highway from milepost 8.0 to milepost 9.5, on both sides of the highway, though the FEMA mapping seems to have misplaced the actual route of the highway through its floodplain. No other significant floodplain resources exist until the confluence of SR-18 and SR-167, where smaller floodplain resources exist on both sides of the highway. There are three areas to the south of SR-18, and multiple areas to the north, on both sides of the highway from milepost 14.5 to milepost 16.0. At milepost 16.5 a floodplain area continues on the eastern side of the highway though milepost 18. On the western side of the highway from milepost 17.5 to milepost 19.5, a significant floodplain area stems from the Green River, intersecting the highway project area. Three floodplain areas are influenced by the project area from just south of milepost 20.5 through milepost 21.5 Small portions of floodplain are influenced on the west side f the highway from about milepost 22.3 to milepost 24.3. Near the end of the project area, milepost 26 through the intersection with I-405, two floodplain areas exist in the 300-ft buffer, on the west side and a portion across I-405 on the northeast side of the highway.

Riparian resources

Small portions of riparian forests are within the 300-ft project area buffer from milepost 9.4 to milepost 13.5 (see Figures 60, 61, and 62, "Existing Aquatic and Fish Resources"). The buffer intersects four riparian forest areas along the western edge, interacting with small streams descending from the western valley wall. Only one stream in this stretch of highway contains more extensive riparian resources, at about milepost 10.7. Where SR-18 crosses SR-167, there is a very small amount of riparian forest impacted on the western side, extending up Peasley Canyon. No more significant riparian resources exist in the project area until milepost 22.3, where an off-ramp buffer overlays a portion of an extensive riparian forest on the east side of the highway. The buffer intersects two other significant riparian forests at about milepost 23.6 and 24.7, on the eastern side of the highway. No other riparian forests of note exist in the project area.

Forest cover resources

There are no significant forested areas in the project area, other than in riparian areas as discussed above.

Groundwater resources

The entire SR-167 project crosses a shallow alluvial aquifer that is closely tied to river water levels in the Green, White, and Puyallup valleys. Near Auburn the alluvial aquifer overlies a deeper aquifer in sands deposited by meltwater from receding glaciers. These alluvial and recessional delta aquifers are the primary water sources for the City of Auburn, and are tapped by wells operated by Kent, Algona, Pacific, Sumner, and the Valley Water Association.

The Pierce County section of the project (milepost 5.7 through 11.2) is within a CARA designated to protect groundwater quality in the Puyallup and White river valleys (see Figure 46, “Sole Source Aquifers / Critical Aquifer Recharge Areas in the Study Area”). Projects within this CARA are required to take special measures to prevent groundwater contamination. From milepost 6.4 to 6.9 the project abuts the northern boundary of the Central Pierce County Sole Source Aquifer. This sole source aquifer was designated by the U.S. EPA to protect an important aquifer in the extensive glacial drift deposits that lie south of the Puyallup River. Stormwater runoff must be treated before it is allowed to infiltrate into sole source aquifers.

The entire King County section of the project (milepost 11.2 to 26.2) is in the South King County Groundwater Management Area, where groundwater quality is regulated by a High CARA that covers the Green and White River valleys. The Cedar River Sole Source Aquifer overlaps the northern edge of the study area, but does not come in contact with SR-167.

Fish Resources

Eight species of salmonids occur in streams that cross or are otherwise within the project area: chinook, coho, pink, chum, steelhead, sockeye, coastal cutthroat and Dolly Varden/bull trout. Chinook and Dolly Varden/bull trout are listed as threatened under the Endangered Species Act. All species utilize the Green River (primarily as a migration corridor) where it crosses the project area at MP 19. Chinook, coho, steelhead, and coastal cutthroat utilization (rearing and possibly spawning) occurs in both the mainstem and tributaries to Springbrook Creek and Mill Creek. An unnamed tributary that flows into the White River at RM 1.3 is utilized by coho, steelhead, and chum.

Distribution of salmonids in and near the project area is depicted in Figures 60, 61, and 62.

Hydrologic fragmentation

Traditional impact analyses have focused on how projects affect natural resources within the footprint of the highway. For instance, wetland impact assessments are usually based on the area of wetland that might be filled by the project. However, linear transportation projects often have impacts on hydrologic resources that go well beyond the highway footprint. Road fill, drainage systems, and stream crossing structures disrupt natural surface and subsurface flow paths. This isolates wetlands, confines flow on floodplains and alluvial fans, decouples floodplain areas from rivers, and reduces aquifer recharge from seepage zones and recharge soils. We refer to these types of impacts as hydrologic fragmentation.

Reducing hydrologic fragmentation can be an important component of project mitigation. Multiple culverts or bridges can be used to connect wetland habitats and restore wetland flow paths through the highway prism. Bridges and culverts can also be used to reconnect confined and decoupled floodplain areas. This type of floodplain restoration can help mitigate floodplain impacts and meet local compensatory flood storage requirements. Alluvial fan dynamics can be restored using multiple crossing structures that allow channels to migrate and shift where they cross the highway. Impacts to groundwater recharge can be addressed using BMPs for stormwater infiltration. Seepage zones can be reconnected to alluvial aquifers and downslope wetlands using subsurface drainage systems that convey water through the highway prism.

We have used GIS-based mapping of wetlands, floodplains, alluvial fans, seepage zones, and recharge geology to identify locations where the existing highway may be fragmenting hydrologic resources. These are shown in Figures 63, 64, 65, and 66, and are discussed below.

The southernmost part of SR-167 in our study area crosses the valley floor of the Middle Puyallup and Lower White Subbasins. Near the confluence of the White and Puyallup rivers between milepost 6.2 and milepost 7.9, the highway covers several areas of coarse alluvial soils that provide high rates of groundwater recharge. Most of the adjacent lands are covered by pasture and undeveloped land, so there is potential to use stormwater infiltration BMPs to recover groundwater recharge lost from paved areas. As SR 167 crosses into the Lower White River subbasin between milepost 8.0 and milepost 13.4, it bisects a series of wetlands associated with a ditch that drains the west side of the valley floor. The highway also crosses the bases of several alluvial fans that emerge from ravines carved into the valley walls. Existing development severely constrains restoration of most of these alluvial fans, but there is potential to restore upslope alluvial fan processes on one forested fan (site HFA5, near milepost 12). South of the SR-18 interchange between milepost 12.5 and milepost 13.6, SR-167 intersects a major seepage zone that feeds aquifers and wetlands on the White River valley floor east of the highway.

At the SR 18 interchange, near milepost 13.4, SR 167 crosses into the Mill Creek subbasin, and bisects an extensive complex of wetlands and floodplains. Mill Creek runs parallel to SR-167, and crosses the highway in two locations. At each of these crossings, near mileposts 16.1 and 17.5, the highway confines the floodplain and blocks overbank flow paths. In several other locations the highway acts as a levee and decouples historical floodplain areas from Mill Creek. In most locations existing land uses preclude significant floodplain restoration, but there are three sites (HFF9, HFF6, and HFF5, near mileposts 15.3, 17.5, and 18.5, respectively) where new crossing structures could be provided to link decoupled and confined floodplain areas. These sites also provide opportunities for reducing wetland fragmentation.

The SR-167 bridge over the Green River, near milepost 19.1, does not confine the floodplain because levees and reservoir operations effectively disconnect the lower Green from its historical floodplain. However, there are several sites near the Green River where there is potential to restore groundwater recharge from coarse alluvial soils covered by the highway.

North of the Green River between milepost 21.7 and milepost 26.2, SR-167 runs along the base of the bluff that divides the Covington uplands from the Green River valley floor. This geologic transition contains important seepage zones and groundwater recharge areas that are disrupted by the highway. SR 167 confines floodplains at the Mill and Garrison Creek crossings, but existing land uses upstream and downstream of the highway limit opportunities for restoration. The highway also crosses two alluvial fans at the mouths of ravines that drain the western edge of the Covington uplands. Wetlands cover the lower ends of these fans, just upslope of the highway. Wetlands associated with Panther Creek line the upslope side of the highway, but are generally not fragmented by the highway. The exception to this is the lower Panther Creek wetlands (near the interchange between SR-167 and I-405), where the highway separates a relatively intact wetlands system from ponds and floodplain areas on the valley floor.

V. Potential Transportation Impacts

Why do we assess transportation project impacts?

Our purposes for assessing project impacts are to:

- Gain an understanding of the type, extent, and value of regulated natural resources within the highway project area and lands immediately adjacent to it
- Evaluate the relative value and importance of regulated resources and provide guidance that facilitates sound avoidance and minimization decisions

Which transportation projects were assessed?

For planning purposes, we were directed by the project office to estimate the potential natural resource impacts of two corridor-wide enhancement scenarios:

Scenario One:

- One additional highway lane in both directions throughout the entire SR-167 corridor, plus a 4-ft buffer in each direction.

Scenario Two:

- Two additional highway lanes in both directions, plus a 4-ft buffer in each direction.

In developing each scenario, we assumed that, where medians currently exist between the northbound and southbound lanes, additional lanes would be located in the median before new hard surface was added to the outside of the existing highway. No attempts were made to estimate the additional pavement required to modify interchange on- and off-ramps to each scenario.

At what assessment level were they assessed?

Our assessment should be considered "qualitative" in nature. We used digital datasets to identify the location and extent of regulated natural resources; our calculation of added pavement for each of the development scenarios is an estimate. These facts introduce sufficient error to preclude quantifying potential impacts with any level of certainty. In addition, the two general development scenarios only accounted for adding new lane surface and didn't include revisions to existing on- and off-ramps or bring sub-standard shoulder widths up to current highway standards. For these reasons, all potential natural resource impact numbers should be considered rough estimates based on the two generalized scenarios.

How was the SR-167 corridor subdivided?

For general planning purposes, the SR-167 corridor was subdivided into nine highway segments. Three highway segments were previously established and represent future transportation projects. These distinct highway segments were maintained for our impact assessment purposes. Because the King/Pierce County line is a regional boundary for WSDOT highway projects, a segment break was added there. By using the established segment boundaries and the one addition segment break at the county line, nine highway segments were established for impact assessment purposes. Appendix F contains more details on how we developed the polygons, how we defined highway segments, and how we estimated natural resource, stormwater runoff, linear feet of stream reported to have anadromous fish, and water quality impacts.

What potential impacts were identified?

The SR-167 corridor was subdivided into nine highway segments for estimating natural resource impacts for each of the two corridor development scenarios. Estimated potentially impacted wetland, riparian, and floodplain resources for Scenarios 1 and 2, the addition of one or two lanes to SR-167, by highway segment, are summarized below in tables 1 and 2.

In this analysis we assume that water quality impacts will be fully mitigated within the WSDOT right of way using best management practices contained in the Highway Runoff Manual. We also assume that water quality impacts cannot be compensated on a watershed basis at this time. However, the flow impacts of adding impervious areas currently can be mitigated within the immediate watershed and outside of the immediate highway right-of-way, therefore they are listed as project impacts.

Text following the tables gives some of the assumptions and limitations and further clarifies the data shown in the tables.

Table 1. Potential impacts, by highway segment, Scenario 1.

One additional highway lane plus a 4-ft buffer, in both directions, throughout the entire SR-167 corridor.

Segment	New Impervious Surface, Acres	Flow Control Need, Acre-feet *		Wetland, Acres	Riparian, Acres	Floodplain, Acres	Impact to Anadromous Fish Habitat (Linear Feet)	Salmonid Species Present in Segment **
		Grass	Forest					
1	3.6	11.9	4.7	21.2	0.0	0.0	0	
2	15.9	41.4	18.6	0.0	0.0	0.0	1073	CHMF, Coho, STWI
3	13.1	31	13.9	8.6	0.0	0.0	361	Coho, STWI
4	7.5	21.8	9.8	0.0	0.0	0.0	0	Coho, STWI
5	8.4	26.3	11.8	5.6	0.0	2.0	89	CHFA, Coho, STWI
6	14.8	29.1	13.1	3.5	0.1	4.1	31	CHMI, CHMF, Coho, Pink, SOCK, DBT, STWI
7	6.6	22.3	10.0	1.5	0.0	0.2	19	Coho
8	12.0	39.5	17.7	6.0	1.8	0.6	132	CHFA, Coho, STWI
9	7.2	23.3	10.5	13.1	1.2	0.2	33	Coho
Total	**89**	**246.6**	**110.1**	**59.5**	**3.1**	**7.1**	**1738**	

* Grass represents the existing land cover in most of the project area, recommended by the HRM for pre-developed conditions in urban areas. Forest represents the pre-European settlement land cover in the project area, and is the default land cover scenario used in Ecology's Stormwater Manual for Western Washington.

** Species Codes: CHFA = Fall Chinook (ESA listed - Threatened), CHMF = Fall Chum, Coho = Coho, STWI = Winter Steelhead, Pink = Pink, SOCK = Sockeye, DBT = Dolly Varden/Bull Trout.

Table 2. Potential impacts, by highway segment, Scenario 2.

Two additional highway lanes plus a 4-ft buffer, in both directions, throughout the entire SR-167 corridor.

Segment	New Impervious Surface, Acres	Flow Control Need, Acre-feet *		Wetland, Acres	Riparian, Acres	Floodplain, Acres	Impact to Anadromous Fish Habitat (Linear Feet)	Salmonid Species Present in Segment **
		Grass	Forest					
1	6.2	13.5	5.6	25.2	0.0	0.0	0	
2	27.8	50.3	22.6	0.0	0.0	0.0	1073	CHMF, Coho, STWI
3	18.2	34.8	15.6	8.8	0.0	0.0	362	Coho, STWI
4	14.0	26.8	12.0	0.0	0.0	0.2	0	Coho, STWI
5	14.7	31	13.9	19.7	0.0	4.7	126	CHFA, Coho, STWI
6	21.4	34.1	15.3	14.3	0.5	11.8	57	CHMI, CHMF, Coho, Pink, SOCK, DBT, STWI
7	11.6	26.1	11.7	9.0	0.0	0.4	44	Coho
8	21.0	46.3	20.8	26.6	5.9	1.5	220	CHFA, Coho, STWI
9	12.6	27.4	12.3	42.8	2.5	0.4	58	Coho
Total	**147.4**	**290.3**	**129.8**	**146.4**	**8.9**	**19.0**	**1940**	

* Grass represents the existing land cover in most of the project area, recommended by the HRM for pre-developed conditions in urban areas. Forest represents the pre-European settlement land cover in the project area, and is the default land cover scenario used in Ecology's Stormwater Manual for Western Washington.

** Species Codes: CHFA = Fall Chinook (ESA listed - Threatened), CHMF = Fall Chum, Coho = Coho, STWI = Winter Steelhead, Pink = Pink, SOCK = Sockeye, DBT = Dolly Varden/Bull Trout

Stormwater runoff impacts

We used methods from the HRM to estimate the storage volumes needed to mitigate impacts to stormwater peak flows and stream channel erosion. We have assumed that this mitigation will include full retrofit of the existing highway lanes. To provide a consistent index of stormwater impacts, we have also assumed that detention is the only method used to control project runoff. Infiltration, Low Impact Development, and other Best Management Practices could be used to reduce these storage needs where soils and topography are suitable.

We estimated project storage for two pre-developed land cover scenarios. Grass represents the landscaped fill material that makes up the existing land cover in most of the project area. The HRM recommends using the existing land cover as the pre-developed condition for projects in urban catchments. Forest represents the pre-European settlement land cover in much of the project area, and is the default pre-developed land cover scenario used in Ecology's Stormwater Manual for Western Washington.

Wetland impacts

Wetland impact estimates vary substantially between individual highway segments (Tables 1 and 2).These numbers represent an estimate of wetland area impacted by each development scenario. Wetland quality and condition information was developed and presented in the wetland avoidance and minimization part of this report. This is a fey factor that must be considered, along with wetland area, when estimating overall wetland mitigation needs. Wetland impact estimates likely represent worst case scenarios for use in early project planning. Impacts will likely be reduced by innovative avoidance and minimization efforts in the project planning and design phases.

Riparian impacts

The remaining forested riparian resources are concentrated in the northern portion of the study area, for both scenario's, in segments 6, 8, and 9. Most of the riparian forest stems from streams running down the eastern wall of the valley and intersecting the highway.

Floodplain impacts

Possible floodplain impacts exist mainly in the northern portion of the study area, in segments 4-9, with segment 6 (Green River) holding the largest amount. One large FEMA floodplain polygon, in project segment 2, crossed the existing pavement of the highway and is assumed to be an error in FEMA floodplain mapping, based on field observations. To correct this assumed error, the floodplain designation was removed from the raised bed of fill associated with highway lanes and median in this project segment.

Impact to Anadromous Fish Habitat

Eight species of salmonids occur in streams that cross or are otherwise within the project area: chinook, coho, pink, chum, steelhead, sockeye, coastal cutthroat and Dolly Varden/bull trout (see Tables 1 and 2 for fish species presence by segment). Chinook and Dolly Varden / bull trout are listed as threatened under the Endangered Species Act. All species utilize the Green River (primarily as a migration corridor) where it crosses the project area at MP 19. Chinook, coho, steelhead, and coastal cutthroat utilization (rearing and possibly spawning) occurs in both the mainstem and tributaries to Springbrook Creek and Mill Creek. An unnamed tributary that flows into the White River at river mile 1.3 is utilized by coho, steelhead, and chum. Distribution of salmonids in and near the project area is depicted in Figures 60, 61, and 62, Existing Aquatic and Fish Resources.

Direct project impacts to fish include potential migration barriers at stream crossings and potential channel modifications to fish-bearing streams that flow within or adjacent to the project area. Impact lengths by segment are reported in Tables 1 and 2 and represent the length of fish-bearing stream occurring within the assumed additional footprint of the two scenarios. Inconsistencies were noted in the hydrography layer used to develop this information; a more detailed evaluation of impacts based on aerial photo-based correction of the hydrography information is provided in Appendix F.

VI. Potential Mitigation Opportunities

In this chapter, we synthesize watershed characterization information developed earlier to identify landscape areas having the greatest potential to: a) mitigate transportation impacts; b) maximize environmental benefit while reducing mitigation cost; and c) ensure long-term viability of functions mitigated.

How were mitigation sites identified?

We developed potential wetland, riparian, and floodplain restoration site datasets primarily through aerial photo interpretation of the study area and supplemented by existing natural resource inventories, locally identified natural resource recovery areas, and limited field verification. See our revised watershed characterization methods document (Gersib et al. 2004) for detailed descriptions of the methods specific to the development of each natural resource database.

The potential restoration site databases consist of 5,599 polygons, including:

- 3,775 unique riparian polygons
- 1,747 unique wetland restoration polygons
- 67 unique floodplains polygons
- 10 unique stormwater retrofit polygons

Each database has extensive polygon attribute data that can be found in the GIS data bundle CD.

How were mitigation sites prioritized?

Because of the diverse mitigation needs within the study area, three priority mitigation site lists were developed. The first, a stormwater flow control priority list, identifies and prioritizes potential wetland, riparian, and floodplain restoration sites and stormwater retrofit sites having potential to provide off-site stormwater flow control for SR-167 projects within the study area. The second, a natural resource mitigation priority list, identifies and prioritizes potential wetland, riparian, and floodplain restoration sites having potential to maximize environmental benefit within the study area. The third is a list of restoration sites that are prioritized for benefit to anadromous fish habitat restoration.

Data on the following key environmental attributes were compiled on each candidate mitigation site:

- All ecological and biological process condition rankings
- Anticipated environmental benefits gained if the resource is restored

- The candidate site’s proximity to the transportation project
- Type of natural resource
- Site targeted for restoration in a local or regional recovery plan
- Site on or adjacent to publicly owned parks, schools, or property
- Type of natural resource
- The size of the candidate restoration site

Detailed methods for prioritizing stormwater flow control and natural resource mitigation sites are described in Gersib et al. (2004) and detailed data and results are presented in Appendix A.

When developing the priority list for natural resource mitigation, all potential riparian, wetland, and floodplain restoration sites were initially considered candidates for natural resource mitigation. Attributes of each candidate site were then compared to criteria established for all landscape attributes, except proximity, an attribute which is specific to flow control. This process eliminated sites from further consideration and, at the same time, ranked remaining sites. The resulting natural resource mitigation priority list is presented in Appendix B.

We initially considered all potential riparian, wetland, and floodplain restoration sites when developing the priority list for anadromous fish habitat restoration. Attributes of each candidate site were then compared to established criteria. This process eliminated sites from further consideration and, at the same time, ranked remaining sites. The resulting anadromous fish habitat restoration priority list is presented in Appendix C.

What are the mitigation opportunities within the study area?

Substantial opportunities exist to mitigate natural resource impacts of SR-167 corridor transportation projects as well as other future transportation projects in the study area. Numerous opportunities also exist to mitigate stormwater flow control impacts upslope of the highway.

A total of 61 potential floodplain, wetland, and riparian restoration sites and stormwater retrofit sites met minimum ranking criteria and were prioritized for use in the mitigation of stormwater flow control impacts. This prioritized stormwater flow control list and data used in the prioritization process are presented in Appendix A. Each potential stormwater flow control mitigation site was mapped within the appropriate stream sub-area and presented in Appendix A.

A total of 828 potential floodplain, wetland, and riparian restoration sites met minimum ranking criteria and were prioritized for use in natural resource mitigation. This prioritized natural resource mitigation list and data used in the prioritization process are presented in Appendix B. Each potential natural resource mitigation site was mapped within the appropriate stream sub-area and presented in Appendix B.

The potential floodplain, wetland, and riparian restoration sites which met minimum ranking criteria were prioritized for use in fish habitat restoration. This prioritized list and data used in the prioritization process are presented in Appendix C. Each potential fish habitat restoration site was mapped within the appropriate stream sub-area and presented in Appendix C.

To facilitate initial evaluation, we compiled additional cost and ownership information along for the highest ranking sites on the stormwater flow control and natural resource priority lists. This information is presented in Appendix G.

Do any of the sites conflict with King County's Farmland Preservation Program?

King County has informed WSDOT that they do not want mitigation projects on Farmland Preservation Program properties (for which the county owns development rights), nor in Agriculture Production Districts. Exceptions may be made where the soil is not suitable for agriculture and the farm is not in production. Mapping these types of sites is infeasible due the shifting nature of agricultural production and the lack of information on some of these sites. However, if WSDOT environmental staff look closely at a potential mitigation site that appears to be used for agricultural purposes, we recommend that they talk to staff of King County's Office of Rural and Resource Programs.

Were any of the sites given closer examination?

Average per acre land values (based on appraised tax valuation including the value of property improvements such as homes) were acquired for the top 45 potential restoration sites for overall ecosystem function and top 20 sites for stormwater flow control to provide insight into the range of land acquisitions costs. Average per acre land values for range from a low of $2,944 per acre to a high of $112,138 per acre. The number of parcels, or, when available, the number of landowners for each potential mitigation site were identified to provide perspective regarding acquisition feasibility. Individual mitigation sites range from one single landowner to a high of 13 landowners in King County and 19 parcels in Pierce County. One site had 52 landowners and was not further considered due to the difficulties of managing a site with so many parcels. Methods used and detailed results may be found in Appendix G.

How should this information be used?

Potential mitigation sites identified through watershed characterization can serve five key roles.

1. Most importantly, watershed characterization provides the transportation project engineer with alternative mitigation opportunities that cannot be acquired elsewhere. In urban or urbanizing areas where conventional means of identify-

ing mitigation opportunities result in few options, the value of watershed characterization products increases.

2. WSDOT invests millions of dollars each biennium to mitigate or compensate for natural resource impacts. The use of watershed characterization to target mitigation sites having the greatest potential to maximize environmental benefits ensures that WSDOT investments in environmental mitigation are maximized.

3. At times, the environmental permitting process has resulted in project delays that ultimately result in added project costs. Watershed characterization methods provide a science-based systematic process for evaluating and prioritizing many potential mitigation sites. This process and the accompanying supporting documentation can expedite the permitting process and reduce the risk of project delays associated with environmental permitting.

4. WSDOT is responsible and accountable for providing quality transportation infrastructure at the lowest cost. As mentioned earlier, mitigation costs can be in the millions of dollars and, at times, costs are higher than expected because there are few, if any, permitable mitigation options. Watershed characterization identifies new mitigation options that the project engineer may consider when conventional site selection tools are unable to identify cost effective options.

5. Watershed characterization, if completed early in project planning (or prior to the planning) facilitates the use of mitigation banks. These mitigation banks have potential to compensate for the future impacts of entire highway corridors or multiple projects within the same general area and can result in added potential for the restoration of larger sites that provide substantial environmental benefits at a reasonable cost.

Priority mitigation lists developed through the watershed characterization process represent the products of a science-based, landscape-scale screening tool. Products should be considered options or opportunities that will require further site-specific assessment by regional biologists prior to the selection of a preferred mitigation option. The watershed characterization technical team stands ready to support the SR-167 environmental staff in any manner they deem appropriate to support environmental permitting.

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Oversize Maps